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Purpose The *Air Force Journal of Logistics* provides an open forum for the presentation of issues, ideas, research, and information of concern to logisticians who plan, acquire, maintain, supply, transport, and provide supporting engineering and services for military aerospace forces. It is a non-directive, quarterly periodical published under AFR 5-1. Views expressed in the articles are those of the author and do not necessarily represent the established policy of the Department of Defense, the Department of the Air Force, the Air Force Logistics Management Center, or the organization where the author works.

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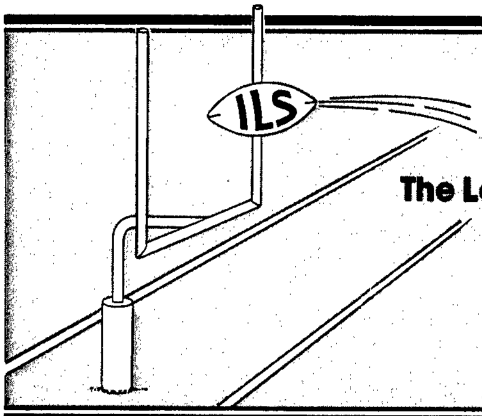

The Lombardi Approach to Integrated Logistics Support (ILS)

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Introduction

During tenure as the head coach of the Green Bay Packers, Vince Lombardi became very concerned over the performance of his players. He felt the tremendous variety and complexity of offensive and defensive strategies had overshadowed the players' understanding of the fundamentals of football. From this simple conviction sprang one of his most famous lines, "This is a Football!" His objective was quite clear—*Back to Basics*.

I see a need to adopt a similar back-to-basics philosophy for logistics planners. During my career as an acquisition logistician, many innovative concepts and amazing technologies have evolved. However, my concern is that the acquisition community in general and logisticians in particular may be losing sight of the fundamental concepts of acquisition logistics and integrated logistics support (ILS). The field of logistics has become so specialized, that many people only work one small area of just one element of logistics and never really gain a true understanding or appreciation of the total field and how their job fits into it. It is therefore my intent to go back to the beginning and explore the meaning of acquisition logistics and integrated logistics support; why logistics is gaining an ever-increasing level of importance; and some of the responsibilities of the educational system, the organization, and the individual in initializing or reaffirming the fundamental principles of ILS.

Returning to the Basics

If we are going back to the beginning, we should start with some basic definitions. According to AFLCP/AFSCP 800-34, *Acquisition Logistics Management,* acquisition logistics is:

> The process of systematically identifying and assessing logistics requirements and alternatives, analysis, and resolution of integrated logistics support (ILS) deficiencies, and the management of ILS throughout the acquisition process.[1]

In this definition, the statement that acquisition logistics is " . . . the management of ILS throughout the acquisition process" is generally accepted to mean that once the end item with its total logistics support package has been fielded, the acquisition process is complete and so is acquisition logistics planning. Usually, around this point in an acquisition, it becomes the responsibility of the Air Force Logistics Command (AFLC) air logistics centers to provide the support and, eventually, after the program management responsibility transfer, the management of the system or equipment for the remainder of its deployed life.

The definition of acquisition logistics mentions the term "integrated logistics support (ILS)." ILS differs from acquisition logistics in that ILS is a "cradle to grave" process; whereas, acquisition logistics is the logistics planning accomplished during the acquisition cycle. ILS planning starts before a system even enters the formal acquisition process. As using commands prepare the Statement of Operational Need (SON) to identify a deficiency in their ability to accomplish the mission, they will include the logistics needs, requirements, and constraints they want to impose on the new system. Following production and deployment, ILS planning will continue throughout the system's deployed life until it is removed from the inventory. Department of Defense Directive (DODD) 5000.39, *Acquisition and Management of Integrated Logistics Support for Systems and Equipment,* describes ILS as:

> A disciplined, unified and iterative approach to the management and technical activities necessary to:
> a. Integrate support considerations into system and equipment design.
> b. Develop support requirements that are related consistently to readiness objectives, to design, and to each other.
> c. Acquire the required support.
> d. Provide the required support during the operational phase at minimum cost.[2]

What exactly does this mean? First, it stipulates that the entire ILS process must be diligently applied (disciplined). No two acquisition programs are alike and, likewise, no two ILS programs in support of acquisitions will be alike. However, regardless of the size of the program, *all* logistics elements must be assessed for possible program applicability. As a brief refresher, the ten DOD identified elements of logistics are:

(1) Supply Support.
(2) Technical Data.
(3) Facilities.
(4) Manpower and Personnel.
(5) Packing, Handling, Storage, and Transportation.
(6) Training and Training Support.
(7) Support Equipment.
(8) Computer Resources Support.
(9) Maintenance Planning.
(10) Design Interface.[3]

When it has been determined which specific logistics elements will be a part of the acquisition, each will then be pursued according to its policies, procedures, and practices.

Inherent in the definition of ILS is the need for these ILS elements to be managed as a single entity (unified). The interrelationship of ILS elements to each other is such that a change in one element could greatly affect another. For example, if people change the design of a piece of support equipment, they must change its technical orders and engineering drawings, maybe retrain operators or maintainers, modify spare parts, or reprogram software. The change will likely affect not only supportability factors but also cost, schedule, and possibly performance.

For the ILS program to be effective, it must be periodically and systematically reviewed and updated as the program progresses (iterative). Acquisition programs are extremely dynamic. Numerous factors can change the way a program advances through the acquisition cycle. Results of internal trade-off studies, congressional or higher headquarters directed changes, or the user's modification of performance or support requirements can be valid and necessary but also devastating to the timely development and deployment of the logistics support capability for a system. All changes, no matter how insignificant they may seem, must be evaluated for their impact on logistics support.

Summarized, the four objectives of ILS require that:

(1) As systems are developed, emphasis must be placed on designing-in, to the maximum extent feasible, those capabilities that improve and enhance logistics support while maintaining a balance between cost, schedule, performance, and supportability. Included are the early assessment and development of the optimum support concept considering operational requirements, user constraints and needs, and existing support capabilities.

(2) As the logistics support package for a system is being planned, developed, and produced, a paramount concern must be the identification, acquisition, and distribution of the right combination of logistics resources, coupled with the development of the optimum support concepts that will maximize system readiness at minimum life cycle cost. We must not only be concerned with the support of the end item (aircraft, missile, radar site) but must also be concerned with support of the support system. Support equipment and training devices also need technical data, spare parts, trained operators and maintainers, facilities, and support equipment.

(3) As the acquisition process progresses, deciding how the logistics support system must function, and its composition, is only part of the challenge. In most programs, industry plays a—if not the—major role in planning, designing, and fielding the system. It is incumbent upon program logisticians to translate logistics requirements into contractual requirements and then, more importantly, to ensure these requirements are met. Acquiring the required support involves activities, such as the development of the proper logistical inputs for the solicitation (specification, special provisions, statement of work, data), to the logistics evaluation performed during the source selection process, to the periodic meetings with industry to assess the progress of the process. We should not, however, lose sight of the fact that a significant portion of the logistics resource needed to support a system may come from existing DOD inventory (support equipment, spare parts). Consequently, equal attention and coordination must be given to the identification and acquisition of these resources through existing government channels.

(4) After a system is fielded, logistics support is put to the true test. If the first three ILS objectives described have been achieved reasonably well, we should then be able to provide maximum support to the deployed system at minimum cost. However, it would be unrealistic to expect every facet of the logistics infrastructure to perform or be available as planned. It is therefore necessary that a continual evaluation of the support status be performed and follow-on actions taken to refine planning, correct deficiencies, and develop workarounds.

Throughout this explanation of acquisition logistics and ILS, one word emerges as the kingpin of logistics—integration. Integration is not the exclusive domain of logistics. All aspects of a program must be integrated and that is the job of the program manager.

Failure to integrate can certainly lead to problems. For example, a General Accounting Office (GAO) report cited a $163,843 vacuum-heated maintenance stand that one year after delivery was still in storage because the Air Force had not received a technical order on how to use it.[4] Without operating and maintenance data, a piece of support equipment can be rendered useless. And, without the support equipment, the end item it supports may also be rendered useless. More serious examples of failure to integrate exist, but it is not the purpose of this article to point fingers at mistakes, but rather point toward solutions.

Why the Need for Better Logistics Planning?

It has only been within this decade that the supportability of systems has attained coequal status with cost, schedule, and performance. As a result of this increased emphasis on supportability, the need for knowledgeable and experienced logisticians has grown. The following factors are by no means all inclusive, but do reflect some of the major influences on the need for better logistics planning:

- Readiness and sustainability (a significant part of our war-fighting capability).
- More demanding deployment requirements.
- Logistics support structure increasingly vulnerable.
- Increasing competition for resources.
- Increasing congressional and Office of the Secretary of Defense (OSD) involvement.
- System sophistication and rapidly advancing technology.

Readiness and Sustainability

Readiness is the ability of forces, units, weapon systems, or equipment to deliver the output for which they were designed. The word "ability" encompasses reliability, maintainability, availability, capability, survivability, and supportability. Sustainability, on the other hand, is the "staying power" of our forces, units, weapon systems, and equipment often measured in number of days.[5] Remember the poem that begins, "For want of a nail, the shoe was lost" and concludes with "For want of the battle, the kingdom was lost; all for the want of a horseshoe nail." The availability of the nail in the supply system became of great concern to the horseman. In today's terms that nail would be a nonreparable (throwaway) item. We are still having availability problems with needed throwaway items, but we are experiencing an even more alarming situation as reported in the *Military Logistics Forum* magazine in October 1987:

> As federal investigators unfold what may well be the biggest counterfeit scam in history, the U.S. military and some of its major prime contractors are discovering that their bolt bins—and weapon

systems and equipment—are rife with counterfeits that might not hold up under operational stress.[6]

The article goes on further to say that "Between 10 percent and 50 percent of the grade-8 bolts bought by five major Army vehicle makers are counterfeit." These percentages convert to quantities in the millions. I would suspect that those who have these bolts installed in their systems are now concerned not only for the bolts' availability in the supply system but also with reliability. Unfortunately, sometimes the availability of extra parts in the supply system does little for sustainability when reliability is absent, as exemplified by the seal on the space shuttle "Challenger" or the alleged unqualified components used to build the Inertial Measurement Units for the Peacekeeper missile guidance system. The readiness and sustainability capabilities of a system are most noticeably influenced through the combined efforts involved in system design and logistics planning.

More Demanding Deployment Requirements

In efforts to give Air Force combat commanders the greatest amount of flexibility and maneuverability with their weapon systems and minimize vulnerability, we have created ever more demanding deployment requirements. As an example, at no time in the history of the US Air Force have we operationally deployed an intercontinental ballistic missile (ICBM) to anywhere but a fixed underground silo. Now we are developing the rail-garrisoned version of the Peacekeeper missile that will be an above-ground mobile system launched from railroad cars. This certainly improves the missile's survivability, but it will take some farsighted and innovative planning to provide support.

What about future space systems! In the past, we designed spaceborn equipment with great concern for its reliability and a relatively low concern for its maintainability. Why? Because once it is sent up, we would never touch it again. We wanted it to last a long time (reliability), but we never planned to fix it if it broke once it was deployed. But now with the Space Shuttle, the future National Aerospace Plane, and the US plans for a manned orbital space station, that which we send into the heavens we may retrieve to repair back on earth or while in orbit. Now it becomes of vital interest to design space systems for ease of maintenance. With these new space capabilities, we have entered into a whole new realm of maintenance planning. If you think working on a system in chemical and biological clothing is difficult, imagine doing maintenance in a cumbersome space suit in zero gravity. Space logistics is alive and well, but it is going to take innovative minds, unbridled from the conventional ways of thinking, to develop new approaches of support to cope with these challenging deployment requirements.

Logistics Support Structure Increasingly Vulnerable

You may at one time heard someone say the United States is a safe haven simply because we have not fought a modern war or major conflict against a foreign enemy on US soil in many decades. We may have been somewhat of a safe haven in the pre-1950s, but it is certainly not true today. Just for a moment, let us suppose we could go to the Soviet Union and roll back the silo covers on their ICBMs. And let us further suppose the Soviets wrote the names of the targets on the warheads, much like we did on bombs during World War II. What do you think their targets would be? I would bet that among the targets would be AFLC's air logistics centers and many of the major defense contractors. Why? Because they are the major sources we rely on to give us that sustainability so necessary to a war effort. Without the repair and resupply of parts, we would be like the kingdoms of old. If one king wanted to capture the castle of another, he would surround the walls of the enemy and control, capture, or destroy the resources of the local area. It would be just a matter of time before the castle under siege would run out of supplies and would be forced to surrender. So too with us—without a source of repair and resupply, it would only be a matter of time before we could fight no more.

While stationed in Vietnam, I saw firsthand, but only now realize, just how delicate a logistics infrastructure can be. At Da Nang and surrounding air bases we had some of the most feared aircraft weapons—Spooky, Stinger, Puff the Magic Dragon, Shadow, Spectre, Cobra helicopters, F-4s, A-6s, and many others. On several occasions Viet Cong "Zappers," wearing nothing but a loin cloth and rubber sandals made from discarded tires, and carrying satchel charges, infiltrated the base and not only blew up aircraft but also destroyed maintenance, storage, and servicing facilities. It becomes painfully obvious that the enemy forces do not necessarily have to engage our weapon system in battle to neutralize it. All they have to do is neutralize our ability to repair or service it and they have accomplished much the same objective.

One way of decreasing the vulnerability of our logistics support system is not to have it in or near areas of probable conflict. For many of our current aircraft systems, when we deploy, we must not only deploy the organizational maintenance capability but in many cases a large portion of the intermediate maintenance capability. This not only increases vulnerability of the support system, but it also decreases the combat commander's maneuverability and flexibility, not to mention the strain it puts on our strategic and tactical airlift forces to move all the equipment. Each time combat commanders must relocate, they must pack up their logistics support. The bigger the logistics package, the more cumbersome and time-consuming the move. Increased system reliability can go a long way toward eliminating the need to deploy the much needed, but nevertheless, burdensome support resources. The days of wars being fought along a fixed front are gone. We must be prepared at any time to go anywhere. We must be able to provide maneuverability and flexibility to the weapon systems while decreasing the vulnerability of our logistics support structure.

Increasing Competition for Resources

We all have experienced those times when we have been asked to do more with less. Within the government we once again find ourselves in that unenviable position and must do more with less resources. Acquisition, support, and personnel funding in FY88 was bleak. The next few years do not look much better. AFM 25-1, *Air Force Management Process,* identifies manpower and materials as two of the resources that require a high level of management attention. Manpower is undeniably a major issue today. Because of financial constraints, reductions in the DOD military and civilian work force levels have become a reality. Programs, like Rivet Workforce, are combining the skills of multiple Air Force specialties in an effort to use man-hours more efficiently while allowing a reduction in our total force structure. Systems are being designed such that software can take the place of

humans, as seen in the design of the C-17 where there is no flight engineer's position. However, we must not forget a very important point. When the furor of manpower reductions subsides, we must face the fact that we will still employ a lot of people. Not surprisingly, we do several interesting things to our federal employees. For instance, we promote them, we reassign them, and sometimes we fire them. Because we promote, retire, and fire, we need a continual stream of new people (military and civilian) entering government service. The "baby boom" of the late 1940s and early 1950s created a large pool of people from which to pick. But those people are now in their late 30s to early 40s. If these baby boomers are in federal service, the majority are not new recruits but are mid-level managers now. We do not perform the day-to-day maintenance of our deployed systems with 30- and 40-year-old people. It is younger people, those in their late teens and 20s, both male and female, that are doing most of the actual hands-on work. Because of the drop in this country's birthrate over the years, today there are not nearly as many young people from which to choose. Getting them in federal service is just part of the problem. How do we keep them? The best of both military and civilian government employees are being enticed away from government service by more lucrative opportunities with industry.

So far we have mentioned only the human resource. What about material resources? A very interesting article appeared in the *Military Logistics Forum* magazine. The article addressed our country's increasing dependency on foreign sources for many of the raw materials needed in our manufacturing industries:

> The debate over the United States' dependence on imports is not black and white, but is shaded with numerous views. Most experts agree the country is vulnerable. The debate centers on how vulnerable and whether the country has sufficient stockpiles and assured sources to ride out a crisis—or a war.[7]

You may wonder, why does the US put up with some of the political, social, and economic shenanigans of many countries? Well, maybe this same article can shed some light on that question:

> The 1978 rebel invasion in Zaire's mining country seems like a minor event today. But, the disruption in cobalt production that it caused in the central African nation is still well remembered by the U.S. defense industry officials as they witness a growing alliance of foreign materials.[8]

As an example, the article went on to say, "Cobalt is an essential mineral for producing the high-temperature burners and turbines for today's advanced jet engines" and "Zaire accounts for almost 40% of U.S. cobalt imports." This is just one raw material. The US imports many different raw materials from numerous other foreign sources. One of our major suppliers of platinum is the Soviet Union. We get chromium from Yugoslavia. The list goes on and on. It does not take much thought to realize that from raw materials comes the metals from which industry makes our parts. Without the raw materials, our readiness and sustainability could be seriously affected.

Increasing Congressional and OSD Involvement

The basic acquisition process has been under attack for many years. It is said to be too lengthy, cumbersome, and loaded down with bureaucratic red tape. Warranted or not, program offices have been receiving quite a bit of guidance and direction on how to do the acquisition process from high level people. As pointed out by Colonel Gene Bartlow, who at the time of his article was Chief, Congressional Activities Division at the Pentagon:

> The growth of congressional committees and staffs associated with defense has been escalating in recent years. Ten years ago, four congressional committees wrote legislation on defense; today DOD is shepherded by 24 committees and 40 subcommittees.[9]

It is not only the Legislative Branch that is heavily involved in acquisition policymaking, but also the Executive Branch. I do not profess to know what in our political process causes the Executive mandating of initial operational capability (IOC) dates for major systems. But, I do know of the support impacts when an IOC date is "locked in concrete" while individuals are still debating whether a system is even needed or how it will be deployed. High levels of concurrency in development and production/deployment, as were experienced on the B-1B and Peacekeeper Missile systems to meet a directed IOC date, will continue to drive us to longer delays in reaching organic capability and a greater dependency on contractor support for longer periods of time. This long term reliance on contractor support has in several instances left the military open to public criticism, when in fact it may have been in response to direction beyond the military's control.

The difficulties faced by the program manager in trying to develop, produce, and field systems were emphasized by Mr Frank Carlucci, in testimony before the Senate Committee on Armed Services, when he stated, "Program Managers and industry initiatives are often stilted by over-regulation."[10] He went on further to note that in 1986 there were 114 directives related to acquisition, compared to 15 in 1961 and 25 in 1977, and that studies indicated it costs 8 cents out of every contract dollar to satisfy congressionally and DOD imposed management systems and data requirements. Congress and our President, in their own way, are trying to strike a fair balance between military and social programs. However, they may be causing the defense community to spend more than less on the acquisition and support of our weapon systems because of what appears to be an attempt on their part to micromanage the DOD acquisition process.

System Sophistication and Rapidly Advancing Technology

We no longer rely on a plum bob lying on the ceiling of the aircraft to tell the pilot he is flying inverted. As a nation, our technology is advancing so rapidly that sometimes we have trouble keeping up with ourselves. It is hard to believe that today one of the major limiting factors as to how fast an aircraft can fly, climb, and perform maneuvers is not so much the design or materials, but rather the human occupant. But that is performance. What about support?

Take, for instance, the area of avionics/electronics. Components today are being designed with significantly greater capabilities and, at the same time, in much smaller sizes. Miniaturization permits a greater variety of capabilities to be inserted into the system, thus increasing system complexity. As the functions of these systems become more complex, their design is even more complex with the addition of an internal diagnostic fault detection/isolation capability commonly known as built-in-test (BIT). BIT can simplify the maintainer's job by increasing the speed at which problems can be detected, thus reducing system downtime. It also

minimizes support equipment requirements because the support equipment function is now an integral part of the mission equipment. BIT can be designed to diagnose and fault isolate a problem to the system, subsystem, line replaceable unit (LRU), and even shop replaceable unit (SRU) level. BIT is intended, in most cases, to replace what is a very labor-intensive, manual fault isolation process, performed by maintenance personnel, using external test equipment and technical orders. Since BIT software can typically do the fault detection and isolation much faster than a human, it has significantly reduced total repair times and increased system availability rates. Generally, the higher the level of BIT accuracy required, the greater the development and production costs. Furthermore, the increased complexity caused by the addition of BIT produces still another part of the system that must be supported. However, the advantage of quicker fault detection and isolation, and the corresponding increase in system availability rates, more than offset the added cost of BIT acquisition and support.

The presence of BIT in an equipment item or avionics subsystem does not necessarily eliminate the need to have technical order procedures and the appropriate support equipment available for fault detection/isolation. If the BIT fails to function properly, we must rely on those fault detection/isolation procedures in technical orders and the associated support equipment to do the job. Therefore, maintainers must also be trained on the manual procedures. The use of more and more BIT is the wave of the future, but it may be a long time before we can do away entirely with the manual backup diagnostic capability.

Responsibilities

We have made tremendous headway in developing all types of computer programs to help us manage individual subdisciplines within logistics. We have an Automated Technical Order System (ATOS) to speed up the preparation and distribution of technical order changes and an Engineering Data Computer Assisted Retrieval System (EDCARS) for storing and manipulating engineering drawings. We have a computerized Logistics Support Analysis Record (LSAR) for storing contractor generated information on logistics resource requirements. We have the Computer-Aided Acquisition and Logistics Support (CALS) initiative that is attempting to determine the best ways to tie together many of the current independent logistics and engineering data bases so a single terminal can have access to multiple sources of information. But, what we do not have is a computer program that can do the sometimes intricate analysis and integration of logistics requirements. Maybe someday artificial intelligence, coupled with expert systems, may be able to tackle this function, but for now we must rely on our own brainpower. Here is where understanding the basics of logistics comes in. I am not advocating we stop pursuing innovations in our logistics planning process. I am saying we need to refresh the experienced logistician and properly educate the novice on the very foundational elements of ILS. I would not limit this education to just logisticians. Program managers, engineers, budgeteers, or anyone else affected by the logistics support requirements for a system should have a fundamental understanding of the logistics process and how it interrelates with their area of responsibility.

Educational System

Before specifically identifying responsibilities of our education institutions, I think it would be advantageous to understand the difference between education and training. It may appear to be a game of semantics, but within the Air Force when it comes to determining who will provide the education/training, what the course content will be, the methods of instruction employed, resources required, or instructor qualification, it does become an important matter.

Although the concepts of education and training share common elements, they have important differences. Education and training represent two different focuses on the learning process. Typically, training is targeted on the acquisition and mastery of a set of relatively concrete and specific procedures, skills, or techniques directly related to the performance of highly specific jobs or sets of tasks. By contrast, education focuses on the learning of concepts and ideas, emphasizing the understanding, comprehension, analysis, and application of this knowledge. The educational process promotes the assimilation of systemized knowledge; develops mental faculties; and improves judgement, evaluative, and analytical abilities, and breadth of understanding. It develops the ability to think, judge, and act when confronted with new and unique requirements in novel contexts. The consumers of training and educational resources and programs need to understand this distinction so they can accurately assess their needs.

My focus leans to the educational side. Give those whose jobs are directly involved in or interface with the acquisition logistics/ILS planning process the ability to "think, judge, and act." The Air Force or any other service's educational institutions that have curriculums dealing with the acquisition, deployment, and/or support of systems or equipment should:

a. When teaching courses in individual subdisciplines of logistics (provisioning, technical orders, reliability and maintainability) or courses that impact logistics (program management, test and evaluation, or configuration management), be sure to include a discussion of how that topic fits into or is affected by the overall logistics planning scheme.

b. Provide logistics consulting support to those actually involved in the acquisition and support of systems and equipment. Not only will this help solve a real-world problem, but it also provides an opportunity to further educate.

c. Make use of institutional knowledge by publishing and public speaking. Faculty members should spread the logistics word by sharing wisdom, ideas, and experiences.

d. Keep in close contact with the people supported. Seek their advice for course improvements, assess their areas of weakness, and adapt.

e. Keep up to date on current acquisition policies and procedures. Become familiar with some of the significant acquisition programs currently underway. Know of their proposed strategies, support concepts, and performance and support requirements.

Organization

An individual's organization can play a key role in the educational process. Though my comments and recommendations are directed at logistics and logistics related organizations, all the following actions can be applied to any function's educational or training requirements:

a. Work with your employees to determine educational needs and prioritize them.

b. Develop an employee training file to track needs, priorities, and completions.

c. Become aware of what logistics and logistics related courses are available and when they are offered. Know more than just the course titles; become familiar with the course content. DOD 5010.16C, *Defense Management Education and Training (DMET) Program,* is a very good source for just this kind of information.

d. Establish two-way, open communications with educational institutions so both may provide and seek assistance from the other.

e. Establish an in-house, formal or informal, education program while waiting for formal course quotas to become available. The program could be as simple as a reference library of various documents (regulations, manuals, magazine articles, or course documentation obtained from formal schools) or as complex as periodically scheduled presentations on various logistics topics, such as the curriculum offered by the Deputy Program Manager for Logistics Course conducted by the Air Force Acquisition Logistics Center at Wright-Patterson AFB, Ohio.

At times it is just too busy in the office to let anyone go away for school for a couple of weeks, even if the course would be of great value to the employee. Rethink priorities on this matter for two reasons. First, the opportunity to get a seat in a particular class may not come around very often, so one should seize the opportunity when it presents itself. Second, the payback from an employee's absence may be greater in the long run than temporary loss on the job. Remember two old schoolhouse sayings, "If you think education is expensive, try ignorance" and "There is nothing more frightening than ignorance in action."

Individual

Probably the greatest single influence on an individual's logistics education is the individual himself. Most of us, at one time or another, have been given a job to do but received little or no instruction on how to do it. We call it "Being Thrown to the Wolves." However, most of us handled it the same way. We seized the initiative and learned most, if not all of it, on our own. There is no reason that same approach cannot be applied in part to developing or reinforcing our understanding of the basics of logistics. Do not wait to be put into a formal course. Start the educational process on your own. Other suggestions include:

a. Determine and prioritize all educational needs and share them with the supervisor.

b. Find out what educational opportunities are available to meet individual needs. When in an academic environment, remember it is just as important to be an effective student as it is to have an effective teacher.

c. Get into the practice of reading about logistics and systems acquisition to broaden individual knowledge and learn from the successes and failures of others.

d. Actively participate in logistics seminars, workshops, and symposia. Time permitting, join some professional society associated with logistics such as the Society of Logistics Engineers (SOLE). Activities such as these will ensure frequent contact with others involved in similar functions and allow a tremendous crossflow of information and ideas.

e. Develop the mental habit of thinking integration. When first aware of a program change, perform a quick mental assessment of the impact the change will have on the logistics system. Eventually, a more thorough assessment of the change will certainly have to be done, but this initial mental assessment tends to surface major issues, which under more detailed evaluation, will surface others.

f. Learn the fundamental principles involved in other disciplines associated with logistics (systems engineering, configuration management, test and evaluation, or manufacturing). Logistics requirements, needs, and constraints are better visualized and understood when individuals are familiar with other disciplines that can affect them.

Conclusion

Logistics has always been, and will continue to be, one of the most critical necessities of war. Our future successes in logistics, both in peace and in conflict, will be won by those individuals that understand and can perform the fundamentals of logistics planning. Technological and conceptual advances in the field of logistics are undeniably needed, but one must always have some baseline from which to start innovation. That baseline is an understanding of the elements of logistics, the processes that help identify, quantify, and justify these needed resources, and some familiarity with logistically associated disciplines.

Notes

[1]AFLC/AFSCP 800-34, *Acquisition Logistics Management*, 13 April 1987, p. 1-1.
[2]DODD 5000.39, *Acquisition and Management of Integrated Logistics Support for Systems and Equipment*, 17 November 1983, p. 2-2.
[3]Ibid., p. 2-1.
[4]*Dayton Daily News*, "Congressman Blasts Contractors," 22 September 1985, p. 3.
[5]JCS Pub 1, *Dictionary of Military and Associated Terms*, 1 June 1987, p. 229.
[6]*Military Logistics Forum*, "A Flood of Bad Bolts," October 1987, p. 38.
[7]*Military Logistics Forum*, "Raw Materials: How Much Is Enough?" 8 February 1988, p. 26.
[8]Ibid., p. 26.
[9]*Program Manager*, "Air Force Acquisition Management: Is There A Better Way?" March - April 1986, p. 13.
[10]Hearings, Defense Procurement Policy and Management, U.S. Congress, Senate Committee on Armed Services, 18 July 1981, 97th Congress, 1st session, Washington DC/GPO 1982, 76 pages.

Best Article Written by a Junior Officer

The Executive Board of the Society of Logistics Engineers (SOLE) Chapter, Montgomery, Alabama, has selected "Manpower—The Critical Resource: A New Statistic for Reliability and Maintainability Application" (Summer 1988 issue), written by Captain Bruce M. DeBlois, USAF, and Captain Milton H. Johnson, USAF, as the best *AFJL* article written by a junior officer for FY88.

Air Force Modification Programs—Interaction of Air Force Logistics Command and Air Force Systems Command

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This two-part article (second part to be published in Spring issue of AFJL) discusses Air Force modification programs and the interaction of AFLC and AFSC. Part I will introduce the importance of the modification process and the problems of AFSC/AFLC interaction, describe treatment of AFSC/AFLC interaction in the various guidance documents, and provide a review of previous studies and analyses. Part II will present results of informal interviews and give an analysis of key issues.

Part I

Introduction

> The Department of Defense (DOD) sustains its weapon systems for an effective United States defense posture in two ways. The first, and best known, is through the design, development, acquisition, and deployment of new weapon systems. The second way is the modification of existing systems to add new capabilities, to correct deficiencies, and/or to extend their operational life. In recent years the modification of existing systems to achieve desired capability has been increasingly advocated as the quickest and most cost-effective way to achieve a modern force under severe budget constraints. (3:2)

This statement is as true today as it was in 1984. As the cost of new systems continues to increase and the federal budget, especially the defense budget, "receives closer scrutiny and harsher criticism," this second method becomes more and more attractive. (3:2)

The funding for modifications has grown significantly over the last 10 years and is projected to continue growing in the Five Year Defense Plan (FYDP). Although reductions in modification funding have appeared in the most recent fiscal year (FY), as a result of across-the-board reductions imposed by Congress, the overall trend for funding continues upward (Table 1).

FY	**Funding*	*FY*	**Funding*
82	$2,251.3	(proj)89	$2,093.2
83	2,564.9	(FYDP)90	3,264.5
84	2,841.2	(")91	3,475.8
85	3,225.5	(")92	3,326.2
86	2,684.2	(")93	3,701.3
87	3,123.8	(")94	4,111.7
88	2,034.7		

*(procurement $ millions)

Table 1: Aircraft Modification Funding (12:31,101-107; 13:C-24, F-1, H-7 - H-13; 14:C-43 - C-49, F-13, F-32; 10).

As a result of the increasing funding for modifications, there has also been increased interest in the process of modification management. Numerous studies have examined the process, particularly as it pertains to Class IV and Class V modifications. These two classes of modifications are fully defined later, but for now they can be considered the types which return a system to full mission capability or add new capability to the system. (16) These studies have tried to analyze various problems in the process and, in the following case, describe the modification process through development of a model.

> In 1983-84, as graduate students at the Air Force Institute of Technology (AFIT), Wright-Patterson AFB, Ohio, 1Lt Harold Stalcup and I researched the Air Force aircraft modification process and created a conceptual model of the process and its policy structure. The information was drawn from regulations, earlier studies, and informal interviews with policymakers and modification experts at command and higher levels. Subsequently, I became an Air Force Systems Command (AFSC) program manager for the F-111 Digital Flight Control System (DFCS) modification program. During this program, I became heavily involved with the Air Force Logistics Command (AFLC), and the question developed: How should AFSC and AFLC relate? No real guidance existed to show the two program managers how to interact, despite my observation that an increasing number of Class IV modifications were being assigned to AFSC for development. In AFSC the program managers tend to follow AFR 800-series regulations, while in AFLC they rely on the AFR 57-series regulations. This experience suggested that the topic of interaction between AFSC and AFLC on modification programs deserved further study, particularly in the area of regulatory guidance.

The problem described can be stated succinctly as follows: Can better guidance be provided to facilitate the interaction of AFSC System Program Office (SPO) personnel with AFLC Weapon System Program Managers (SPM) during the AFSC development and production of Class IV and Class V modifications to weapon systems under AFLC control?

In order to determine whether guidance can be provided, it is necessary first to determine the nature of the relationship between the commands during modification programs. Secondly, the treatment of modifications under current regulations must be examined. It is possible that some regulation outside the standard series, or some passages in the 800-series and 57-series regulations, do adequately treat this interaction. Third, current Air Force thinking on the interaction problems must be investigated. Others may not consider the command interaction a problem. If they do, they may have some suggestions or experiences in correcting the problem. The final objective is to recommend changes to the system.

Background

Definition of Terms

The operational definitions of terms used in this study are:

Aircraft Modification. This term, as defined by DODD 5000.8 and excerpted by the *Compendium of Authenticated Systems and Logistics Terms, Definitions, and Acronyms,* is a "change in an airframe, component or equipment that affects performance, ability to perform intended mission, flight safety, production, or maintenance." (11:459) Missile modification, while not specifically defined in the compendium or the regulations, may be considered to adhere to essentially the same definition.

Classes of Modification. AFR 57-4 (16:5-6) provides a descriptive breakout of modifications into five classes:

Class I - A temporary removal or installation of, or change to, equipment for a special mission or purpose.

Class II - A temporary modification to support research, development, or operational test and evaluation efforts.

Class III - Modifications required to correct a test or service report revealed deficiency when the system has not transferred to AFLC.

Class IV - Modifications to improve reliability and maintainability, to ensure safety of flight, to correct a deficiency which impedes mission accomplishment, to improve logistics support, or to reduce costs.

Class V - Installation or removal of equipment changing the mission capability of the present system configuration.

Basis of Modifications. A Class I or Class II modification is first determined by its temporary nature and then separated into Class I or II by its purpose, as indicated. For Class III and Class IV modifications, the command ownership of the affected system determines the class, given the modification is intended to return the system to full capability. If AFSC still owns the system (Program Management Responsibility Transfer (PMRT) has not occurred), then a modification to correct a deficiency (return the system to full capability) is classified a Class III modification. If AFLC owns the system (PMRT has occurred), then a correction of deficiencies modification will be a Class IV modification. Regardless of command ownership, if a new capability is to be added, or a now useless capability removed, the modification is a Class V modification.

Class IV and Class V modifications originate for a variety of reasons. The most basic reasons are listed in the aforementioned definitions. However, some examples may help bring life to those reasons. When the F-111 experienced uncommanded maneuvers, such as violent pitchdowns on takeoff, which were traced to the flight control computers, a Class IVA modification to correct the threat to safety was started. When the F-111 Bomb Navigation system experienced reliability less than the length of a typical mission, the modification to eliminate the mission deficiency was classified as a Class IVB modification. As often happens, correcting the mission deficiency also led to significantly improved logistics support, which by itself would be a Class IVB modification. (24:24)

Description and Limits of the Study

To meet the objectives of this study, many printed sources and a number of experienced managers in the field were consulted. First, to determine the nature of the relationship between the commands, the author drew upon experience and researched previous studies and articles. Additionally, managers currently involved with Class IV and Class V modifications were informally interviewed. The plan was to define the relationship, establish that a problem does exist, characterize the problems, and find any successes and the secrets of those successes.

To determine how modifications are treated under current regulations, current Air Force (AF), AFLC, AFSC, and AFSC/AFLC regulations, pamphlets, manuals, and handbooks were reviewed. The specific goal was to determine whether AFLC/AFSC interaction is addressed by guidance and, if so, whether that guidance is adequate.

Current AF thinking on these problems was investigated to determine what, if anything is wrong, and to identify ways to fix the problems. This was done by requesting a printout from the AFSC/AFLC Lessons Learned program and conducting informal interviews with managers from both commands and the Air Staff. This information was analyzed to determine the problems and their causes. Alternatives for solving the identified problems were developed based on these sources.

Finally, the study provides recommendations for changes to the process of modification management to improve the interaction between AFSC and AFLC. These recommendations resulted from the analysis of the information provided by these sources and of the alternatives.

The study was limited to examining only one aspect of modification management, and only as it related to Class IV and Class V modifications. The aspect of interaction between AFLC and AFSC was chosen because the author's experience in research and program management suggested the degree and quality of interaction could make the difference between a successful and an unsuccessful program. The choice was encouraged by the project's sponsors (Assistant Deputy Chief of Staff for Product Assurance and Acquisition Logistics, HQ AFSC, and Assistant Deputy Chief of Staff for Materiel Management, HQ AFLC) who were in positions to oversee many modification programs and their problems.

The study was limited to Class IV and Class V modifications because only with those two classes does the AFLC/AFSC interaction become critical. In both classes, the weapon system is under the control of AFLC, and the modification may be developed by AFSC for eventual installation by AFLC. AFLC may develop the modification, but in that case no interaction occurs. AFLC provides system configuration information to AFSC to permit the contractor to design against a baseline, but during the course of the development process, AFLC continues to maintain and modify the weapon system with other changes. If AFSC/AFLC interaction is not maintained, the fully developed modification could arrive at the weapon system for installation only to find it no longer fits because some other modification changed the available space or connections. Redesign at increased cost and delayed installation schedules result.

Current Guidance on AFSC/AFLC Interaction

Guidance documents specific to the modification process are largely grouped into two series, the 57-series and the 800-series. AFLC regards the 57-series as their "bible," and AFSC regards the 800-series as their "bible." Each tends to ignore the other series. An additional regulation in each of the 27-series and the 66-series applies to modifications. Although these regulations provide detailed guidance on modifications,

none specifically guide how AFSC and AFLC should interact in modification management. In this section the pertinent documents will be described in numerical order, with detail provided on any sections that specifically recognize the AFSC/AFLC interaction required for modification management.

27-Series Guidance

The 27-series has AFR 27-8, *Systems and Equipment Modification and Maintenance Program,* which provides policy and assignment of responsibilities for the programming of modifications in the annual Program Objective Memorandum (POM) process. Responsibilities for submission of requirements by each of the two commands are identified—but no mention of command interaction. (15)

57-Series Guidance

The 57-series has two regulations that specifically pertain to modifications. The first, AFR 57-4, *Modification Approval and Management,* provides the "procedures for planning, documenting, obtaining approval, and managing the modification." (16:1) This regulation spells out in detail these procedures. However, its only mention of interaction is found in the Modification Policies section under Implementation Responsibilities.

> Following PMRT to AFLC, there may be some mods [sic] which will require major development. In these cases, AFSC will be tasked to accomplish development by the PMD [Program Management Directive]; however, AFLC will retain the integrating responsibility . . . . In those cases, the two commands will coordinate mutually agreeable arrangements for the management of the program consistent with the PMD. (16:5)

AFR 57-4 also spells out the responsibilities of the two commands—but nowhere else does it consider the interaction between the two nor does it reference AFR 800-2 guidance of program management. (16) This regulation is considered the bible of modification management by AFLC program managers. In contrast, when the author was interviewed by the AFSC inspector general team on her program, the team members involved had never heard of this regulation and were unconvinced that it had application to the Class IV modification program under discussion. The second 57-series regulation that addresses modifications is AFLCR/AFSCR 57-7, *Operational Requirements Purchase Request and Military Interdepartmental Purchase Request (MIPR) Operations,* which discusses funding documents for modifications in detail, but does not address any management issues. (17)

AFSC Pamphlet 57-2, *Modification Management* (23), describes the complexities of modification management for the AFSC program manager. This pamphlet generally provides a high quality guide for the modification manager, including some treatment of the requirement for interaction, or "interface," as the document terms it, with AFLC. It specifically identifies the major AFLC offices with whom the AFSC program manager should develop a formal interface. The pamphlet also warns the manager of the likely existence of modifications in development by other AFSC or AFLC organizations, some of whom might be planning to use the same space, cooling, electrical connections, weight, or computer capacity that is planned for the AFSC manager's modification. (23:8) However, this pamphlet does not recommend or even suggest any mechanisms for preventing or resolving potential problems, other than suggesting the program manager consult the Lessons Learned program managed by the Air Force Acquisition Logistics Center at Wright-Patterson AFB.

Other 57-series regulations exist, but review of them showed that modification management is not addressed, nor is any mention made of the interaction between AFSC and AFLC.

66-Series Guidance

One 66-series regulation addresses management responsibilities for modifications to Air Force intercontinental ballistic missiles (ICBM). This regulation is AFR 66-2, *Single Manager for Modification, Major Maintenance, and Test Programs on Air Force ICBM Systems.* Due to unique features of the ICBM force, any technical alteration to the ICBMs in their launch environment requires a very precise delineation of responsibilities. While the regulation does not address AFSC/AFLC interaction in so many words, it does define their relationship and tasks all commands involved (users, supporters) to develop a management plan that further defines the activity planned and each command's responsibilities. (18)

800-Series Guidance

The AFSC program manager views the 800-series regulations as the "bible" of acquisition. Four 800-series regulations with their command supplements address (or should address) modifications in some way. As has been done so far, they will be reviewed in numerical order.

AFR 800-2, *Acquisition Program Management,* prescribes the system acquisition process and implements the Department of Defense (DOD) Directive 5000.1 and DOD Instruction 5000.2. AFR 800-2's only mention of modifications is on the first page in the introduction, where it states that "All persons involved in acquisition programs, including major modifications, must comply with this regulation." (19:1) Later the regulation lists, as a responsibility of the program manager, compliance with the 800-series regulations, but never mentions the 57-series regulations that guide modifications as indicated. An AFLC supplement to this regulation references AFR 57-4 as guidance for modifications, but that is unlikely to be seen by the AFSC manager. Nowhere does it address the question of interaction between the commands when AFLC owns the weapon system and AFSC is developing or acquiring a major modification. In fact, the only reference to involvement with AFLC discusses the development of the support concept and capability, and the plans for PMRT. (19)

AFR 800-4, *Transfer of Program Management Responsibility,* does not address modifications in the basic regulation. However, the AFLC-AFSC Supplement 1 does provide some guidance on the transfer of responsibility for modifications. It states:

> The AFLC SPM and system or equipment IM [item manager] must be involved early with AFSC in the acquisition planning, design, and development of the systems or equipment for the modification program, and must maintain an active interface to carry out the retrofit of the weapon system. (20:5)

This seems to be a motherhood statement, well intended but

not specific in guidance or setup of responsibilities. No other mention is made of modification management.

AFLCP/AFSCP 800-34, *Acquisition Logistics Management* (21), provides a comprehensive discussion of Class V modification management, but ignores Class IV modifications altogether. As a pamphlet, 800-34 cannot direct actions, but it does provide detailed information on procedures of the modification acquisition process, responsibilities of the various offices and managers, sequences of events as the modification progresses, and potential scenarios that could occur with varying conditions. It also specifically references AFR 57-4 for guidance on modification approval and management. AFLC/AFSC interaction is not separately addressed, but applicable discussion is interspersed throughout the chapter on Class V modifications. For example, it states that ". . . it is possible that the modification would be assigned directly to AFLC. AFLC may then receive engineering support from AFSC if special expertise is required." (21:35-2) Although Class IV modifications are not addressed at all, incorporation of them into this pamphlet would not be difficult. Much of the discussion is applicable to both classes of modifications. Thus, areas of cooperation are fairly well covered, although techniques for achieving successful interface are not discussed.

Previous Studies and Analyses

The earliest study that examined modification management responsibilities was a thesis prepared by Haslam and Berger at AFIT in 1973. They addressed management responsibilities for Class IV and Class V modifications and attributed problems in the process to lack of understanding by process participants of their own and interfacing organizations' responsibilities. Haslam and Berger recommended better operating instructions; periodic briefings on responsibilities of own and interfacing organizations; inspections for compliance with guidance; the use of flow charts (which they developed) to explain the process; and working committees that involve people from the SPO, the System Manager (SM, or today the SPM), the contractor, and the using command to improve the interface. (6:59-64) The flow charts and their suggestions remain usable today.

In 1977 Lieutenant Colonel Reginald M. Cilvik wrote to the Defense Systems Management College (DSMC) for a guide to Class V modification management. This study presents a full consolidation of the guidance provided to modification managers by both AFSC and AFLC. It also addresses intercommand coordination difficulties and lists recommendations for modification management and planning. Cilvik emphasizes that "communications and information flow must be smooth and continuous if the modification is to be effectively controlled." (5:30) He went on to present the result of interviews conducted with AFSC and AFLC managers. He reported an AFLC perception that AFSC managers did not understand the different financial arrangements for modifications and frequently provided very optimistic—unrealistic even—schedules and cost estimates to AFLC. The AFSC perception was that the interface between AFLC and AFSC was not good enough and that the PMD needed to task AFLC to get involved very early in the development process. Both command representatives perceived that "personnel tended to be development or logistics oriented with little cross breeding, resulting in poor understanding of the other point of view." (5:33-37) This supports the premise of the Haslam and Berger study. Cilvik recommends early and continuing involvement of AFLC in the development phases of modifications and emphasizes the importance of "careful attention to the significant coordination and information flow." (5:38) However, he did not recommend any specific methods for implementing these improvements.

In May 1978 Capt Kubecka examined the problems in the Class V modification process in his ACSC research report. He states that a lack of an integrated approach to the process exists and that the problem begins with a split of responsibility for Class V modifications in the Air Staff. Management responsibility for a modification in development belonged to the Deputy Chief of Staff for Research Development and Acquisition (USAF/RD) (now Military Deputy to the Assistant Secretary of the Air Force for Acquisition (SAF/AQ)), but when it entered production, that responsibility transferred to the Deputy Chief of Staff for Logistics (USAF/LG) (now Deputy Chief of Staff for Logistics and Engineering (USAF/LE). This split of responsibilities (still true today) continues down to the SPO and SPM level, where each has separate roles but "integration of effort is definitely needed." (8:31) He reported on an example of the Joint Tactical Information Distribution System (JTIDS), where the original plan called for 25% of the F-15 fleet to be in modification at a time. This was unacceptable to the user and AFLC. The document would never have been printed had the SPO coordinated with the SPM—who at the time was not very involved with the validation phase program. (8:33) Exacerbating the problems of lack of integration are PMDs that do not require AFLC involvement and a lack of temporary duty (TDY) funds for AFLC personnel to attend AFSC planning meetings. (8:30-36) Kubecka recommends that both parties be required to coordinate on cost estimates, that AFLC involvement be required by the earliest modification PMDs, and that the definition of the AFLC involvement be provided by a joint AFLC/AFSC regulation.

Another 1978 Air Command and Staff College (ACSC) paper by Major Bagley also identified the interaction between AFLC and AFSC as a problem prior to the F4-E Advanced Avionics Integration Program (AAIP). (1:36) An attempt to create a Memorandum of Understanding between AFLC and AFSC failed because there was an impression that the regulations already defined the respective responsibilities adequately, and nothing unusual was required. Yet, program realities were different from the regulations, and problems were encountered. (1:36-37) They were able to alleviate the problem by "the assignment of a full-time, fully qualified AFLC expert to the . . . SPO within AFSC." (1:37) The biggest part of the problem was "who's in charge." There were a number of changes being developed in various places, but no one had the overall authority to drive changes, force accommodation, and fund extra costs resulting from these activities. While this specific problem did not involve AFLC, it is very similar to problems AFLC experiences with multiple SPOs at AFSC all trying to use space, weight, cooling, and cockpit space for their own modifications. When the AAIP was created, it provided the necessary centralized planning, which resulted in fewer test resources required, less aircraft downtime, and resolution of deficiencies. Bagley strongly recommended that "a single point of authority and responsibility be identified," and that "the authority and

responsibility between AFSC and AFLC must be clearly defined." (1:54)

Klein and Smigel examined the process in 1979, and found that "faulty communication and coordination exchanges between the commands cause problems that can adversely affect the successful fielding and future supportability of the modified system." (7:60) One approach that seemed to work was to assign an air logistics center (ALC) representative to the SPO and the SPO representative to the ALC. In addition, a Memorandum of Agreement (MOA) between the two commands "delineated the responsibilities of each command and those which cross commands." (7:60-61) One of Klein and Smigel's interview questions addressed the question of split lines of authority and responsibility. The responses indicated this exists and it is a problem. They commented, "Unless one of the two commands has been given the authority to transcend the traditional functional and organizational boundaries separating the two, no one is tasked to perform an overall coordination function." (7:61-62) Klein and Smigel also found that the differences in management approach—project management in AFSC and system/item management in AFLC—were frequently mentioned by their interviewees. When multiple modification actions were underway, the coordination problem became even worse. (7:68) They concluded, "The requirement for a single manager responsibility, and enhanced intercommand [AFLC/AFSC] support, should be interpreted as the outstanding issue in the Class V modification process." (7:80)

Another study done in 1979, a thesis by McIsaac, continued the theme that effective communication and coordination are imperative. He also emphasized the importance of a single manager for the modification, suggesting several alternative lines of authority to accomplish this. (9:49-50,67) McIsaac recommended a new structure be established for the management of modifications, one which would form the single manager with budgeting, authority, and responsibility enough to coordinate the modification process for any one weapon system. (9:82) In effect, he was recreating the SPM structure with emphasis on modifications.

ARINC, a consulting firm hired by the AF Business Management Research Center, in 1980 completed a study that reached similar conclusions. In response to a question about the separate roles of AFLC and AFSC in modification development and implementation, ARINC found:

> . . . the real problem is believed to be caused by a lack of coordination, inadequate PMRT transitions, and less than desirable SPO/DPML [deputy program manager for logistics] and ALC/MAA [not defined] interfaces . . . although development and integration activities are separate and distinct, they must be managed in a cooperative manner, with constant communication and coordination by all involved . . . .(2:3-7)

ARINC also found their respondents strongly believed that there should be strong centralized management "to ensure a proper AFLC-AFSC interface." (2:3-18) The authors looked at cause and effect of these problems, which are excerpted in Table 2. In addition to the cause and effect findings that resulted from the prime thrust of the study, ARINC reported numerous comments received from the 217 respondents.

Many of these comments focused on the lack of a single manager for modifications, the lack of effective communication and interplay among the commands, the need for a modification master plan for each weapon system and the related need to group modifications into logical, time-oriented packages, and the opinion that the system manager lacks

CAUSES	EFFECTS	REMARKS
No single manager	Suboptimum integration of effort during development, acquisition and support phases	Logistics supportability may be adversely affected.
Inadequate communication and coordination	Independent AFLC and AFSC solution of development and support phases	. . . can result in a lack of compatibility between development and support aspects of modification.
Travel funds not approved with modification funding approval	Inability to travel to perform necessary coordination	

Table 2: AFLC-AFSC Interface Problems (2:4-2).

control over the assigned weapon system. ARINC recommended only that the single manager concept be further investigated. Although no specific techniques were suggested, this study did reinforce other studies reported here. (2:5-5)

A study done for ACSC in 1981 by Burleson, Daugherty, et al., further supported the needs described in previous studies in the form of a handbook on modification management. This was the first study that actually provided detail on whom to coordinate with (by job types), what to work with them on, and about when in the process that the described coordination was necessary. It also described a number of the pitfalls common in the modification world, many of which have already been described. The handbook provides a detailed explanation of funding for modification and the coordination required to secure it. (4) Note that modification funds are provided according to type, with each type restricted to only certain uses, budgeted by different commands, and subject to different rules. This study provides an excellent handbook for modification management, with a detailed explanation of modifications and modification funding.

A study was done by HQ USAF in 1984 to develop a Class V Modification Improvement Plan. It was not documented in the conventional style, but briefing slides exist, and the briefer was available for interview during my study. The briefing recommended a single office at the headquarters be established as a focal point for Class V modifications, rather than run the development work through USAF/RD (now SAF/AQ) and the production and implementation through USAF/LE. The study also recommended that modification responsibility should remain with whichever command has PMR for the weapon system; AFSC nonconcurred with this because it would change the basic roles of the two commands. (25) The first recommendation continues the thread of a single focal point for modifications which several other studies have noted. The second recommendation is an institutional attempt to deal with the problems that exist in command interaction.

The final study reviewed was a thesis prepared by Bailey (the author) and Stalcup in 1984 for AFIT. This study developed a comprehensive conceptual model of the aircraft modification process. After modeling the process, the authors identified key issues that drive the behavior of the process and its model. Among these issues were "the management approach to modification of aircraft, the management complexity associated with split management, and the

personality dependence of the entire modification process." (3:112) The management approach used by the SPMs for modification management tended not to be a systems approach; that is, one that manages the overall system as it evolved over time. Instead, the approach tended to be to manage each modification according to its location in the process. Thus a modification to a radar set may be in the same category as an engine modification because they are both in the early planning stage. Other radar modifications may exist, but in different stages, and so are not grouped together. The issue of split management suggests once again the single manager concept. This study also concludes that some one individual must have final authority and responsibility for the modifications to the weapon systems, but that individual must have a thorough understanding of both AFSC and AFLC problems and their reasons for managing their problems the way they do. Personality dependence is another problem for effective modification management. While any management process can be expected to depend heavily on competent, committed people, the process should retain credibility in the system, not be based solely on certain strong individuals. The problem found in this study was that the system had very little credibility with its users, while they feared the loss of the critical individuals on whom they depended. This appeared to be at least partially due to an incomplete understanding of the process. (3:107-142) The Bailey and Stalcup study recommended each weapon system develop a "roadmap" or master plan for modifications, establish mandatory training programs for managers involved in modifications, and establish a single authority point for each weapon system. (3:149)

The review of applicable studies has been long, but a careful examination of the trends of Air Force thinking over the long term of these studies will place the results of the interviews into perspective. Much progress has been made since that first study in 1973. Consideration of logistics supportability and the provision of qualified logisticians to the program offices are now givens. But the problems of split management, inconsistent direction and regulations, and the need for master plans and MOAs seem to still exist, as the interview reviews in Part II will illustrate.

Lessons Learned Program

The Lessons Learned program was created to document either improved procedures that merit consideration or problems that should be avoided on future programs. Lessons Learned (LL) are accessed using code or key words, and the resulting package of applicable LLs are sent to the user. The LL program was accessed for this study as one source of current Air Force thinking on modification management. The same themes appeared. One specific LL was "Close coordination between the Deputy Program Manager for Logistics (DPML) [in the SPO] and the item manager [in the ALC] increases the accuracy of cost estimates for Class V modifications" (22:3) pointing out once again the importance of command interaction. Another applicable LL addresses modifications to the ICBM force. There too is a problem of split management, but in the ICBM case the user is also involved in modifications and maintenance, so the interaction problem is between the ALC and SAC. The LL recommended assignment of a single manager who would be responsible for the interface. One LL proposed a solution to the significant command interface problem faced when a modification is planned to be installed on several different platforms. This solution is a Joint Management Team (JMT), on which are assigned middle managers from each of the platform management offices, whether AFSC or AFLC, the SPOs for the aircraft and the modification, the ALCs involved, and HQ AFSC. The purpose of the JMT was:

> to establish and maintain a formal communications link between the participating organizations, formulate basic interface management policies, act as a formal organization for government review of interface documentation, and address various management issues as they arose. (22:23)

This LL's concept could easily work in the slightly less complex environment of one weapon system and the variety of modifications ongoing, planned, in development, in testing, or in production for that one weapon system. Numerous other LLs were provided which, although not worthy of individual mention, all included the need for strong interaction and communication between AFLC and AFSC in modification management. (22)

References

1. Bagley, Maj Larry, USAF. "F-4E Advanced Avionics Integration Program: Lessons Learned." ACSC Research Report, Air University, Maxwell AFB AL, May 1978.
2. Bailey, S. and Gilbertson, R. "Final Report, Aircraft Modification Management Evaluation." Report by ARINC under contract F33615-80-C-5102, sponsored by the AF Business Management Research Center, Wright-Patterson AFB OH, 1980.
3. Bailey, Capt Rosanne and Stalcup, 1Lt Harold F., USAF. "United States Air Force Aircraft Modification Process: A System Dynamics Analysis." Unpublished masters thesis. Air Force Institute of Technology, September 1984.
4. Burleson, Maj Thomas H. Jr., Daugherty, Maj Gerry R., Fraas, Maj G. Richard, and Ramm, Maj Peter E. USAF. "A Handbook for Air Force Modification Management." #0385-81, ACSC Research Report, Air University, Maxwell AFB AL, May 1981.
5. Cilvik, Lt Col Reginald M., USAF. "Class V Modification Management and Planning: A Guide for the AFSC Program Manager of Less-Than-Major Systems." Study Project Report, Defense Systems Management College, Ft. Belvoir VA, May 1977.
6. Haslam, Capt Donald E., USAF, and Berger, Calvin C. "Evaluation of Management Responsibilities in the Air Force Aircraft Modification Program." SLSR 6-73B, unpublished masters thesis, AFIT, Wright-Patterson AFB OH, August 1973.
7. Klein, Barbara J. and Smigel, Michael A. "An Acquisition Alternative: System Modification to Satisfy Mission Needs." LSSR 16-79B, unpublished masters thesis, AFIT, Wright-Patterson AFB OH, September 1979.
8. Kubecka, Capt Frankie A., USAF. "Class V Modifications: Problems in Improving Existing Weapon Systems and Equipment." #1365-78, ACSC Research Report, Air University, Maxwell AFB AL, May 1978.
9. McIsaac, Capt Richard S., USAF. "A Guide for the AFLC Program Manager of Major Production Class IV and V Modifications." Unpublished masters thesis, AFIT, Wright-Patterson AFB OH, September 1979.
10. US Department of the Air Force, Headquarters. Informal personal interview conducted December 1987.
11. US Department of the Air Force. *Compendium of Authenticated Systems and Logistics Terms, Definitions and Acronyms*. AU-AFIT-LS-3-81. Wright-Patterson AFB OH: AFIT/LS, April 1981.
12. US Department of the Air Force. *The Air Force Budget Fiscal Year 1985*, Comptroller, The Pentagon, Washington DC: Government Printing Office, June 1983.
13. US Department of the Air Force. *The Air Force Budget Fiscal Year 1986*, Comptroller, The Pentagon, Washington DC: Government Printing Office, February 1985.
14. US Department of the Air Force. *The Air Force Budget Fiscal Year 1987*, Comptroller, The Pentagon, Washington DC: Government Printing Office, February 1986.
15. US Department of the Air Force. *Systems and Equipment Modification and Maintenance Program*. Air Force Regulation 27-8, Washington DC: Government Printing Office, 1982.
16. US Department of the Air Force. *Modification Approval and Management*. Air Force Regulation 57-4, Washington DC: Government Printing Office, 1987.
17. US Department of the Air Force. *Operational Requirements Purchase Request (PR) and Military Interdepartmental Purchase Request (MIPR) Operations*. AFLC/AFSC Regulation 57-7, Washington DC: Government Printing Office, 1983.
18. US Department of the Air Force. *Single Manager for Modification, Major Maintenance, and Test Programs on Air Force ICBM Systems*. Air Force Regulation 66-2, Washington DC: Government Printing Office, 1966.
19. US Department of the Air Force. *Acquisition Program Management*. Air Force Regulation 800-2. Washington DC: Government Printing Office, 1985.
20. US Department of the Air Force. *Transfer of Program Management Responsibility*. Air Force Regulation 800-4, AFSC/AFLC Supplement 1. Washington DC: Government Printing Office, 1985.
21. US Department of the Air Force. *Acquisition Logistics Management*. AFLC/AFSC Pamphlet 800-34. Washington DC: Government Printing Office, 1987.
22. US Air Force Logistics Command. Lessons Learned Package with transmittal letter. Lessons Learned Data Bank, Wright-Patterson AFB OH, 3 November 1987.

Continued on page 34 ▶

Military Logistics: From History to the Perspective of Its International Expansion

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Evolution of Logistics

In his book, *The Art of War*, published in 1873, General Jomini defined logistics as "the practical art of moving armies." In his definition he included "providing for the successive arrival of convoys of supplies" and "establishing and organizing lines of supplies." If one assembles these words, he arrives at a definition of logistics as "the practical art of moving armies and keeping them supplied."

Over one thousand years before the beginning of the Christian era, a Greek expeditionary force laid siege to the city of Troy, far away and across the sea in Asia Minor. Homer's epic account of this gives us a picture of warfare in the early classical world. Logistics problems must have begun to play a part in this, one of the earliest documented battles, when one looks at the artifacts of the era: warriors wore suits of armour that contained advanced features such as articulated shoulder pieces that allowed movement. They also had helmets made of leather covered by boar's tusks, body shields, bronze swords, throwing spears fitted with spearheads, and horse-drawn war chariots.

As civilization progressed and armies grew, so did the materials and miscellany surrounding them. The armies of the early seventeenth century, for example, were huge blundering bodies. A force of 30,000 men might be followed by women, children, servants, and sutlers estimated from 50% to 150% of its size, and it had to drag this huge tail behind it. The troops consisted mostly of uprooted men with no home outside the Army. The accompanying baggage—especially that of the officers—assumed monumental proportions. In one account it is stated that Maurice of Nassau in his campaign of 1610 had almost 1,000 wagons. Of that number about 150 were earmarked to carry his staff and their belongings. The logistics required to support them becomes a matter of interest. As most of the armies consisted of mercenaries, they received just enough support from the army to cover their daily food and clothing. In many instances their company captain would pay for the clothing, arms, and equipment from his own funds or those entrusted to him by the government.

Over the years, commanders of armies began to see the need for an organized method of supply. This was initially established with the sutlers through contracts. Whatever the method of supply, there was always one basic requirement—a need for money. That has not changed over all these hundreds of years!

Commanders also found other logistics problems just as perplexing: the sheer weight of the artillery pieces of the day caused major logistics problems. One piece of artillery weighed almost 5 1/2 tons and had to be dismantled whenever it was shipped. Even broken down, the transport required at least 30 horses for each gun. It was estimated that 250 horses were needed for an artillery train of six cannons, with all of its supporting ammunition of approximately 100 rounds each, plus the powder and engineering tools. The sheer weight of such materials required a complex order of march for the armies both in advances and retreats. In most instances it took the artillery twice as long as the armies to cover a given distance. It is said that at least 20% to 30% of the animals could be expected to die of exhaustion annually.

Later, the concepts of warfare logistics began to change. Two Frenchmen, Le Tellier and Louvois, developed and effectively used the concept of magazines to support waging war. Le Tellier is also credited with establishing and using vehicle parks of wagons which were loaded with provisions and operated by trained personnel. While his technique should not be construed as the beginning of the transportation corps, the concept did have significance in the history of logistics. It could possibly be said that both Le Tellier and Louvois, through their efforts, gave birth to the *first elements of organized logistics*. Their endeavors brought about greater freedom of maneuver and allowed for increased speed of movement covering greater distances.

In continuing this brief review of the history of logistics, we cannot overlook the exploits of Napoleon. His increased use of ammunition by the individual soldier and by artillery gave rise to another form of supply facility—the ammunition magazine. Napoleon also provided for the beginnings of the transport service. His efforts in this area are regarded as classic. He also developed and effectively used the "ordonnateurs" and the "commissionnaires de guerre" in providing supplies to his troops.

Decades later, with the coming of the railroad, came the possibility to move large numbers of men and supplies over great distances in short periods of time. Also during World War I, motorized vehicles came into being as another means of moving men and supplies. Transportation Corps changed its concept. Were it not for the motor-transport companies, many of the advances of the armies of that period would not have been possible. Still, with all of the technological advances, supply of badly needed materials, such as fodder for horses, proved disastrous.

During World War I, and unlike previous wars, ammunition became the greatest quantity of supplies used. It is estimated that in the wars prior to 1914, ammunition constituted less than 1% of supplies. After 1914, the percentage was completely reversed.

Much can be said about the logistics problems encountered in World War II. Machines were improved; they were faster, larger, and more powerful. Greater distances played a

significant role and required the development of new and often untested means of coping with the logistics problems. Added to that, many of the logistics problems of earlier wars were again encountered. All items of supply increased in usage. Subsistence items in particular became a greater percentage of the supplies used and brought about the need for permanent storage bases to respond to the requirements. There was, however, a greater need for repair parts and skilled maintenance personnel to keep the equipment going.

International Expansion

The question of where this leads us in the realm of logistics begins to materialize. Up to the point of 1914, logistics could be categorized as a combination of supply and transportation. After the introduction of motor vehicles and permanent storage facilities, the field of logistics took on a new perspective. There was a need for Maintenance, Storage, Issue, and Receiving activities. There was also the need for Replenishment and Inventory Control, not to mention Equipment Handling, Shipping, and Disposal. Logistics as we have come to know it had come of age. With World War I, logistics, through technology, began to take on an international flair. Since World War II, this concept has become an accepted way of life.

Logistics today has become totally international. We are linked together in an inseparable bond. This is at least speaking from a commercial sense. Military speaking, we are not yet at a point where mutual partners such as those of the NATO Alliance are totally willing to accept the concepts that the term "international" embellishes. Logistics, it is said, is a national responsibility. However, we are fast approaching a period when we will be forced more and more to think international rather than national. Technology and reduced military budgets are pushing us in that direction.

For a long time, member nations of the Alliance have sidestepped the issues and connections between collective security and collective efficiency. This is not surprising when one realizes the number of sovereign states and the different geographic, economic, and political situations that comprise the area. While diversity has its benefits, it also has major disadvantages when each nation attempts to develop its own unique weaponry and supporting logistics systems for an intended mutual defence.

The cost of modern weaponry is rising at an unprecedented rate, driven both by inflation and sophistication of equipment. Every NATO country has an economic problem. This has produced urgent demands to reduce expenditures for defence at a time when many of these countries should be spending more. If NATO nations are to avoid drifting into a situation where increasing costs make them weaker year by year, they must somehow reform the way they spend their money.

One solution to the problem is increasing international cooperation among all NATO members in arms development, production, and logistics support. Although the number of collaborative projects is increasing with such systems as Tornado and the Multiple Launched Rocket System (MLRS), as many coproduction initiatives seem to fail as those that succeed. It therefore becomes imperative that the Alliance address the problems of more efficient use of military resources.

NATO Maintenance and Supply Agency

In the field of logistics the best way to accomplish international cooperation is through the use of an established and experienced logistics agency such as the NATO Maintenance and Supply Agency (NAMSA). NAMSA, the executive agency of the NATO Maintenance and Supply Organization (NAMSO), has been charted since 1958 by the NATO Council as the logistics support organization in NATO. The purpose is to provide logistics support services in peace as well as in wartime for weapon systems held in *common* by NATO nations, with the *objective* of achieving economies and improving the efficiency of logistics support. All NATO countries except Iceland are members of NAMSO and NAMSA.

NAMSO consists of two levels: a legislative and an executive agency (Figure 1). The *legislative level* consists of a Board of Directors, which is directly responsible to the NATO Council. The Board is composed of one representative from each member country plus a representative of the NATO Secretary General and a representative of the Supreme Allied Command Europe, both in an advisory capacity. The Board's role is to define the policy to be followed by the agency. It *approves the annual budgets and personnel establishments*, and *oversees the agency's performance*. In addition, the Board of Directors is assisted by two subsidiary committees: a *Logistics Committee* and a *Finance and Administration (F&A) Committee* which give technical advice before the Board makes decisions. There are also *Weapon System Partnership Committees* (WSPC) for the main weapon systems which NAMSA supports. The role of these committees is to define the particular policy to be followed for the weapon system of their concern. The Board of Directors however retains the right to approve WSPC's decisions. The executive level of NAMSO is the agency called NAMSA which is composed of the General Manager and the organization under his command. It is responsible for developing and implementing plans and policy, and providing required support to the nations.

Important, of course, is the permanent link with our customers: the Army and Air Force Materiel Commands, and to a certain extent the Navy Materiel Commands in the various countries.

To accomplish our mission, a variety of logistics support tasks are carried out. They are grouped into three main categories:

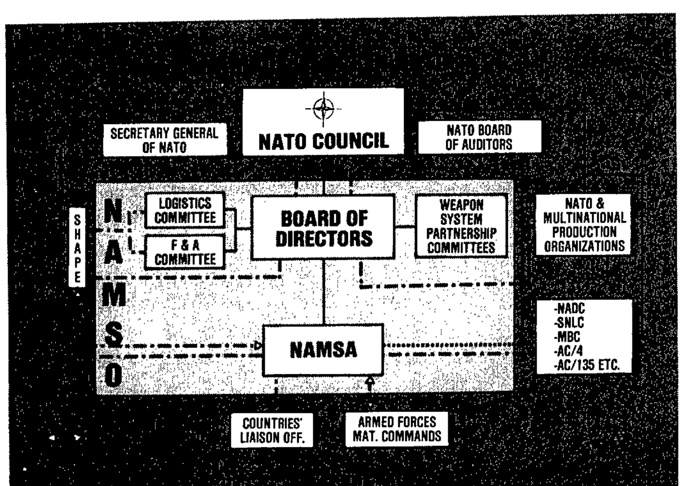


Figure 1.

(1) Supply of spare parts.
(2) Maintenance of equipment.
(3) Technical support of systems.

As stated in our Charter, the requisite is on *common* equipment and *common* support. By centralizing similar tasks and resources and by consolidating the same requirements which many nations have, NAMSA can support equipment more effectively than individual countries.

Supply

In the category, *supply of spare parts,* embracing any weapon system that is commonly supported by NAMSA, *initial provisioning* is one of the main tasks. This is accomplished through the consolidation of procurement and later through the stockage of those items which the participating countries have determined should be a part of the initial range and quantities of spares needed to support the programme. I am referring to both consumable and repair exchange items of supply.

The efficiency and effectiveness of the NAMSA *Procurement* function to support the numerous NATO countries and programmes are worth mentioning. My Procurement directorate awards contracts for about half a billion dollars a year; out of it, around half is going to the US. One of our procurement principles is to encourage international competitive bidding among firms in all NATO countries. In the context of resources available to our Programme Managers, we have currently over 17,000 different potential sources recorded in our source files. Of these about 50% are European and Canadian, and 50% are US. These sources are identified to NAMSA by contractors themselves, by national authorities, and by industrial development organizations. Our source file is unique in NATO and enables us to contact as many potential firms as possible.

Balancing of production or the principle of "Juste Retour" is another aspect of NAMSA's procurement policy. This principle is fully complied with, when the ratio of purchases made from firms in the various nations to billings made by NAMSA to these nations, is 1 to 1. Some nations are above this ratio. We call them well-placed nations. Others fall below and are categorized as worse-placed nations.

Our principal objective is to obtain the most favorable prices; therefore, only the most favorable proposals should be accepted. However, to spread contracts over a large number of firms in 15 different nations as evenly as possible, we apply the following policy: If the cheapest offer comes from a firm in a well-placed nation, we will give the next best offeror from a worse-placed nation the opportunity to match that cheapest offer.

In support of the *procurement of nonrecurring demand items* (we call this process *Random Brokerage),* both current and inactive data are researched and used in providing countries with the required items of supply. This material is ordered by NAMSA and is shipped directly to the customer by the supplier. In areas such as *Mutual Emergency Support,* with NAMSA'S assistance, countries can determine the availability and location of critically short items of supply. In *Configuration Management,* and in *Disposal and Redistribution* operations, NAMSA's assistance is also available.

Maintenance

In the *maintenance of equipment* category, NAMSA provides maintenance service for its customers in two different ways:

(1) Through contractual maintenance agreements with outside contractors. These may be firms or government establishments. This method of support represents about 95% of NAMSA maintenance activity.

(2) In NAMSA's own workshops. We refer to this as "organic" or "in-house." Contractual work performed with industry includes maintenance of missiles and their ground equipment, radar, or communication equipment.

NAMSA's workshops repair and maintain electronic and optical equipment for LANCE and TOW and communications equipment for MNC-controlled facilities. The following general rules and principles govern maintenance support services (overhaul, repair, modification) available to NAMSA's customers:

- As regards maintenance, NAMSA may in principle only act as an intermediary, thus normally providing indirect services (mainly contractual maintenance).
- Every maintenance service provided by NAMSA must, whenever possible, be placed under the control of one of its Programme Offices. These constitute the normal point of contact with the customer.
- Maintenance contracts signed by NAMSA on behalf of its customers have to be awarded in accordance with the rules set forth in the NAMSO Directive on Procurement Policy, unless otherwise specified in the relevant Weapon System Partnership Agreement and/or Logistic Support Directive.
- The procedures to be followed when preparing for and providing maintenance services must be designed to achieve maximum cost-effectiveness.
- Therefore the principle of competition is applied; i.e. the most favourable and responsive bid is accepted regardless of the member country from which it comes.
- Production is balanced among nations to the greatest possible extent following special criteria.
- Sources are normally limited to firms located within NAMSO member countries. European sources are used to the greatest extent possible.
- When all the customer countries of a Programme or a Weapon System Partnership so decide, awards of contracts may be subject to the approval of the NAMSO Board:
  -- Be limited to firms in specific geographical areas.
  -- Be determined by the application of certain criteria designed to give preference to firms located in such geographical areas.

Calibration is another NAMSA service. In performing this function NAMSA saves the participating countries costly expenditure of funds, which would be required to purchase test measurement and diagnostic equipment, and reduces the countries' need for highly specialized personnel to operate such sophisticated equipment.

The Calibration function is performed using either a *Mobile* or a *Static* facility:

(1) For Mobile Calibration, NAMSA technicians travel with air-conditioned workshop vans from country to country and from site to site to calibrate test equipment periodically, primarily for NIKE and HAWK missile systems.

(2) Static Calibration is conducted in a well-equipped NAMSA laboratory in Luxembourg - Capellen, where the teams' calibration equipment is repaired and recertified. The

laboratory also performs calibration services for the E-3A NATO Airborne Early Warning Force aircraft at Geilenkirchen and repairs and calibrates selected materiel of the US Armed Forces stationed in Germany.

Technical Support Tasks

In the third category of *technical support of systems,* NAMSA performs numerous *technical support* functions for participating countries. Some of these are the development of preventive maintenance procedures; the development and maintenance of configuration management programmes for supported weapon and equipment systems; and quality assurance functions relating to failure and deterioration rates of equipment and the production of supply and technical documentation.

These tasks are performed for over 20 weapon and equipment systems (Figure 2). The main systems and their users are shown in the figure. The users, which are listed in alphabetical sequence, include SHAPE because it has not only operational but also logistics responsibilities. The various systems are grouped into Missiles and Rockets, Radar and Surveillance, Communications, and a miscellany of others such as the 155-mm Field Howitzer, anti-submarine Torpedoes, the M113 Armoured Personnel Carrier, and others. Special tasks like procurement of infrastructure funded equipment, consolidated purchase of selected types of ammunition, and calibration of test equipment are carried out on a case-by-case basis and when requested by the nations.

MAIN SYSTEMS AND USERS

		BE	CA	DE	FR	GE	GR	IT	LU	NL	NO	PO	SP	TU	UK	US	SHAPE
MISSILES ROCKETS	NIKE	★				★	★	★			★			★			
	HAWK	★		★	★	★	★	★		★							
	LANCE	★				★		★		★					★		
	SIDEWINDER	★		★	★		★	★		★	★	★	★	★		★	
	TOW		★	★		★	★	★	★	★	★	★		★			
	MLRS				★	★		★		★					★	★	
	PATRIOT					★				★						★	
RADAR + SURV	NADGE/NAEGIS	★		★	★	★	★	★		★	★	★		★	★		★
	AWACS																★
	DRONE CL89/289				★	★		★							★		
	IDS	★				★	★	★		★				★	★	★	★
COMMUNICATION	FWD SCATTER	★	★	★	★	★	★	★		★	★			★	★		★
	SATCOM	★	★	★		★	★	★		★	★	★		★	★	★	★
	NICS/CRYPTO ETC.	★	★	★	★	★	★	★	★	★	★	★		★	★	★	★
OTHERS	FH-70					★		★							★		
	M-113	★	★	★		★		★			★	★	★	★	★		
	F-104						★	★						★			
	TORPEDOES				★	★	★	★		★	★	★	★	★	★		
SPECIAL PROCUR & TECH SERV		★	★	★	★	★	★	★	★	★	★	★	★	★	★	★	★

Figure 2.

According to a NATO council decision of 1952, logistics is a national responsibility. We therefore tailor the support for each system, never attempting to encroach upon national responsibilities. We only get involved when nations see a clear advantage in using NAMSA.

NAMSA Structure

Figure 3 shows the structure of the executive agency NAMSA. NAMSA's personnel strength is about 1,150, of which a little over 1,000 is in Luxembourg. NAMSA is headed by a General Manager who has four Directors and five direct Assistants who form with him the NAMSA Headquarters. Each Director has under his authority a number of Divisions or Programmes. At the bottom of the figure, there are Operational Centers which are directly under the authority of the General Manager. These are:

(1) The *HAWK Logistics Management Office,* co-located with the HAWK Production Office in Paris, France.

(2) The *Southern Depot* located in Taranto, Southern Italy, which is responsible for supplying parts to the Southern Region Nations (Greece, Italy, Turkey).

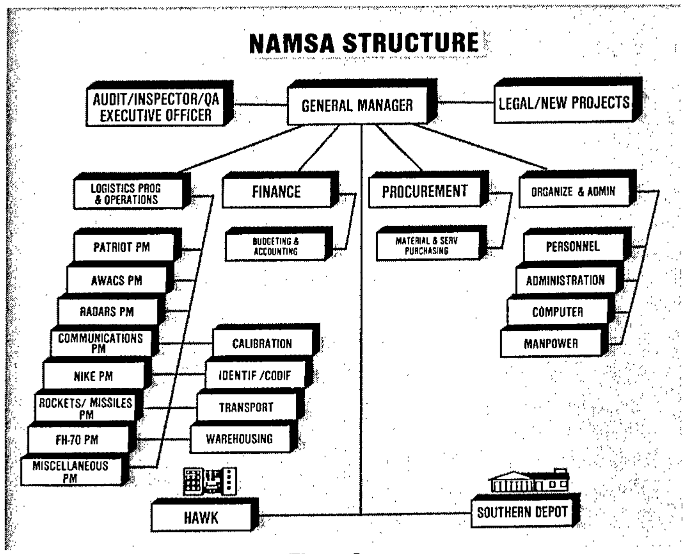


Figure 3.

Summary

NAMSA can provide logistics support to countries in a coordinated way in the three logistics fields of supply of spare parts, maintenance of equipment, and technical support and engineering services.

The aim is to deliver fast, repair quickly, reduce prices through consolidation and competition, reduce investments and operating costs through centralization, and balance contracts among firms in all member nations.

In times of budget constraints and reduced expenditures, the NAMSA concept is a way of the future and of Expanded Logistics Horizons, into the necessary international field.

Most Significant Article Award

The Editorial Advisory Board has selected "Some Thoughts on Combat Support Doctrine (AFM 1-10)" by Major Michael C. Green, USAF, as the most significant article in the Fall 1988 issue of the *Air Force Journal of Logistics.*

USAF LOGISTICS POLICY INSIGHT

Engineering and Services Warfighting Improvements

This year, engineering and services forces in CONUS will be better postured to go to war. Prime BEEF, Prime RIBS, and fire-fighting mobility teams are in the final stages of a restructure which will enhance their warfighting capabilities and make war planning considerably easier. Emphasis is being placed on constructing teams so fewer of them are required to support the typical flying squadron. Additionally, the majority of teams will be tied to their home station aircraft. These improvements enhance combat readiness through increased contact between operators and support personnel resulting in improved training and better contingency planning. Theater planners benefit several ways with the implementation of the new team structure. They will have fewer teams to absorb into and move around in-theater, and teams are more effectively packaged. This will more efficiently utilize engineering and services assets. Finally, more available engineering and services people are postured, further reducing the existing shortfall and providing planners improved capability to respond to mission requirements. (Lt Col Komisarz, HQ AFESC/DEOP, AUTOVON 523-6121)

Construction Cost Management Analysis System (CCMAS)

The Air Force Engineering and Services Center (HQ AFESC/DEC) will be making the new automated parametric CCMAS available for use by the entire engineering and services community. It will be formatted to work on the WANG computer system and should be fielded by Summer 1989. It will also give engineers an automated tool for preparing construction cost estimates and for analyzing estimates provided by design and construction agents. (Mr Burns, HQ AFESC/DEC, AUTOVON 523-6263)

Contracting Guidance During Investigation

Several months ago, the Department of Justice (DOJ) announced they were conducting an investigation into the practices of certain contractors doing business with the Department of Defense (DOD). The investigation has been referred to as Operation "Ill Winds." As a result of the on-going investigation, DOD took interim steps to strengthen the Department's procedures. These steps include the requirement for a Competitive Information Certificate and inclusion of a Profit Reduction for Illegal or Improper Activity clause for certain contracts being awarded to offerors identified in the investigation. The Air Force guidance is contained in AF Acquisition Circular 88-36, dated 21 September 1988. (Major Joseph B. Magnone, SAF/AQCS, AUTOVON 225-1997)

Logistics and Engineering Information Systems

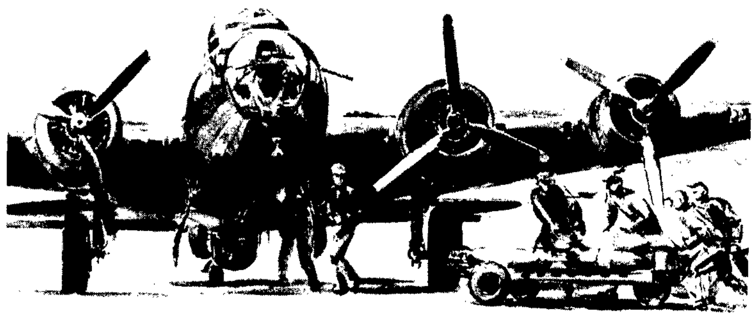
Logistics and engineering information systems play an ever increasing role in our ability to support the mission. Throughout the Air Force, there are more than 600 operational systems and 100 new systems in development to support our functions. These systems have been, and are being, developed to support individual functions at specific echelons. As a result, it is extremely difficult to determine how any single system contributes to the overall process. Recognizing our investment and the need to articulate how these systems fit together, the DCS/Logistics and Engineering (AF/LE) has recently formed a new division devoted to working information systems issues. This division, LE-I, is tasked to develop plans and policy for the use of information in the future. Individuals from each of the logistics and engineering functional areas and the Air Force Logistics Command (AFLC) have been combined in this division so we can start addressing the use of data across functions. (Mr Paul Rowe, AF/LE-I, AUTOVON 225-1015)

CE MWR Construction Program

Major policy changes have occurred within the civil engineering community's Morale, Welfare, and Recreation (MWR) construction program. Revised DOD MWR Construction Funding Policy—approved by Congress on 22 December 1987—groups MWR facilities into four categories, ranging from Category A, Mission Sustaining (library, physical fitness, etc.) to Category D, Business Activities (bowling, golf, etc.). The policy establishes a single construction fund source which eliminates mixing the appropriated funds (APF) and nonappropriated funds (NAF) into a single construction project. Because the single fund source applies to both minor and major construction, it precludes (1) expenditure of APF Operations and Maintenance (O&M) dollars for projects under $200,000 on facilities normally constructed by NAF and (2) expenditure of NAF dollars for projects under $300,000 on facilities normally constructed by APF. Category D activities receive no direct APF support. Civil engineering, however, provides indirect support for all categories (fire and police protection, pest control, Inspector General (IG) services) and continues to maintain and repair MWR facilities with the exception of golf course grounds maintenance, which is an NAF responsibility. Correction of fire and life safety deficiencies remains an APF responsibility. (Ginny Herrington, AF/LEEPO, AUTOVON 227-8902/8957)

The Unsung Heroes of the Air
Logistics and the Air War Over Europe
1941 - 1945

Robert P. Smith
Office of Air Force History
Bolling AFB DC 20332-6098



Painting by John Scott

By promoting strategic and tactical air power as the key to American dominance in the skies over Europe in World War II, aviation historians not only minimize the role logistics played in achieving those victories, but they also do a disservice to those unsung heroes of the air—the ground crews—who kept the Army Air Forces operational. By closely studying the US Strategic Air Forces, Europe, in particular the Eighth Air Force, this article hopes to redress this imbalance and, in the process, shed new light on the study of the air war.

Major General Hugh Knerr, a leading World War II American air logistician, described how, in the early stages of the war, the absence of logistical thought among his colleagues had hampered America's efforts to launch an aviation program capable of defeating enemy air forces:

> Too frequently in the last war we were carried away by our enthusiasm for action and neglected our logistic requirements, with the result that the action had to be canceled or delayed.[1]

As the Commanding General of the VIII Air Force Service Command and later as Lieutenant General Carl Spaatz's Deputy Commanding General of Administration for the US Strategic Air Forces, Europe, Hugh Knerr would play a prominent role in shaping logistics policy for the European Theater of Operations (ETO).

In establishing the Eighth Air Force in England, many logistical planning factors were considered: the construction of air bases and depots; the replacement of aircraft lost in combat; the training of maintenance crews; the storage of fuel, bombs, and ammunition; and the provisioning of thousands of spare parts. General Spaatz remarked:

> In this period of the beginnings of American air power in Europe was also begun the development of the logistical machine which was indispensable to the success of the mission of the Eighth Air Force.[2]

As Commander, VIII Bomber Command, an important component of the Eighth, Major General Ira Eaker experienced firsthand many of the early logistical problems. In September 1942, for example, Eaker cited his transportation situation as "critical"; bemoaned the "long time lag" between the arrival of the heavy group ground echelon and its organizational equipment; called the service groups' tables of organization "archaic and wholly unsuited to the task confronting us here"; and described the construction program in the British Isles as "unsatisfactory."[3]

In March 1942, the American air plan of operations called for the extensive use of British facilities at the outset so operations could begin earlier. Under this scheme the Eighth Air Force would build its logistical system concurrently with operational activity. Air base construction, the core of this program, was hindered however by the shortage of British labor and the slow arrival of US engineer battalions—often without equipment.

As with the air bases, the Eighth's depot system was still largely in the planning stages. Prior to Pearl Harbor, two of the three great depots that were to be the bedrock for the entire Air Force supply system in the United Kingdom had been selected. However, the shortage of labor and materials kept these depots, Langford Lodge in Northern Ireland, and Warton, near Blackpool, comparatively inoperative until 1943.[4] To fill the gap, in 1942, the British, after "determined and persistent objections," bequeathed Burtonwood Repair Depot to the VIII Air Force Service Command. Located near Liverpool, this installation was under the operation of the British, but its facilities were converted easily to American use within a short time. Burtonwood soon became the centralized repair, supply, and maintenance site for all American planes in England and was an outstanding showcase for American efficiency methods.[5] By D-Day, the American construction program in the United Kingdom was complete except for minor repair and expansion work.

The supply and replacement of aircraft to the overseas air forces presented additional logistical problems. Not only was it necessary to furnish planes to build an effective striking force, but aircraft lost in combat or damaged beyond repair also had to be replaced. Writing to Arnold in January 1943, Ira Eaker remarked that "it looks like it is really going to be lack of replacement aircraft and crews, rather than the weather, which limits the number of missions we can do."[6]

From the beginning of the war until April 1943, the shipping space available for water transportation of aircraft was entirely insufficient to meet the needs of the combat units. General Spaatz acknowledged that "everything gets priority (in shipping) over the air forces although air operations over here are of number one importance."[7] It was not until March 1943, that any sort of aircraft shipping policy was established where the Army Air Forces could depend upon a reasonably stable flow of tactical planes. Of the aircraft transported by water from March 1943 to August 1945, 50% were shipped by tankers.[8]

The aircraft shipping program continued to improve with the decision by the Joint Chiefs of Staff to convert Liberty vessels to aircraft delivery ships. The flow of planes shipped by water was considerably stabilized when the Assistant Chief of Air Staff, Materiel and Services, was given authority to schedule sailing dates and name destinations. The combination of these two factors made it possible for the Air Force to deliver planes in good condition and on time.

With the arrival of its Service Command in England in July 1942, the Eighth Air Force had, for the first time, the nucleus of an agency that was to supply and maintain it in combat. As

Eaker phrased it in a 1944 report, "the operational efficiency of the Eighth Air Force will be in large part limited and circumscribed [sic] by the adequacy and effectiveness of the Eighth Air Force Service Command."[9]

Key Service Command officers could frequently be found in the headquarters war room, listening to combat reports or studying operational and intelligence findings. The weekly commanders' meetings, which included the Service Command, usually generated lively discussions on questions of aircraft serviceability and maintenance. According to the official Eighth Air Force history:

> A raid on the continent produced an intense reaction on activities at Service Command Headquarters and its depots and field installations, and showed beyond doubt how in the history of the Eighth Air Force, service and combat were inextricably woven.[10]

The ups and downs of the VIII Air Force Service Command, however, were not the mere result of Eighth Air Force combat developments and administrative experience. They were also a product of the ideas and conceptions in the minds of the Eighth's commanders and other officers, as to the direction logistics would take in the total picture of modern war. In the Eighth the prevailing theory was that the combat factor was predominant and all matters of supply and maintenance were subordinate to it.

The concept at that time, which placed logistics factors last, gained wide acceptance even among commanding officers. General Eaker, for example, announced at a 1943 commanders' meeting, that the top priorities of the Eighth were designated bomber objectives and employment of the tactical air force; the service of these forces was "subordinate though vital."[11] Very few airmen held the opposing point of view. The one exception was Hugh Knerr, who wrote in a December 1942 memo:

> Modern War is rapidly developing into a logistic struggle. The importance of the tactical weapon is therefore overshadowed by the supply organization which supports it. This is a consequence of the mechanization of war. This exchange of relative importance has not been duly recognized, and as a consequence the means for meeting the changed situation has [sic] been neglected.[12]

While his views were never wholly accepted by the air forces' hierarchy, Knerr succeeded in impressing upon them and others the importance of logistics to the future of an independent air force. What is significant is that the history of the Eighth and its service command showed a trend, albeit a very slow one, away from the complete subordination of the "logistical" conception to combat needs.[13]

If air leaders failed to appreciate the relative merits of logistics in the hierarchy of decision-making, they never underestimated the essential nature of proper maintenance or the absolute necessity of spare parts to their operational strength. Aside from the normal attrition of aircraft parts, battle damage took a heavy toll of combat planes, especially during the early days of the war. In January 1943, for example, 48% of all aircraft crossing the enemy coast received battle damage. This continued until the range of fighters had been increased sufficiently to provide escort in deep penetrations into enemy territory. During the 459 operational* days of the Eighth Air Force, the service units repaired 59,644 battle-damaged aircraft. In August 1943, slightly more than 3% of the Eighth's planes were grounded for lack of spare parts, but by December 1944 only .93% were grounded. With a projected inventory of 10,000 aircraft for the period, this indicated the superior work performed by the VIII Air Force Service Command.[14]

During the early years of the war, maintenance services carried a heavy load of repair work. The desperate need for aircraft in most theaters argued strongly for repair of crippled or damaged planes. Thus, air depot and service groups were strained to provide special skills, equipment, and materials needed to meet the demand. After an inspection trip to the United Kingdom in late spring, 1942, "Hap" Arnold cited the maintenance of aircraft as the Eighth's most serious problem. As one possible solution, Arnold suggested Hugh Knerr for command of the Eighth's logistical establishment. Interestingly, Knerr, after he became the Eighth's air service head, took exception to Arnold's criticism and argued instead that "it was creating crews capable of performing maintenance" that affected the command's repair and maintenance activities.[15]

But Knerr's appointment and the use of an additional 27,000 people for aircraft service early in 1943 enabled the Eighth "to maintain more aircraft habitually in commission than we have crews to operate them."[16] The situation improved so dramatically that a War Department special consultant, who visited the Eighth in December 1943, reported to General Eaker that the efficiency of his service command was indicated "by the fact that 75% of your bombers and fighters are being kept in flying condition. This is a most wonderful record and a tribute to your maintenance and supply personnel."[17] He went even further:

> I believe that everyone will agree that "THE UNSUNG HEROES OF THE AIR" are the ground crews who work all night repairing plane battle damage, refueling, loading bombs and ammunition, checking guns, checking and adjusting and repairing engines and instruments in order that the airplanes will be ready for another mission the following day. Were it not for the conscientious, untiring and efficient labor carried on by these men, it would be impossible for the flying crews to carry on the battle with the marvelous record they are establishing.[18]

The problems in maintenance that persisted until 1944 were made all the more serious by a prevailing spare parts shortage, which contributed its share to a far heavier emphasis on repair than had been anticipated or could be regarded as justified except in the context of desperate combat requirements.[19]

As the aerial war intensified, American planes had to be modified to meet combat requirements. Until late in the war, most of this work was performed in the theater by the service units. In 1944, for example, 13,970 aircraft of all types were modified in the European theater. During this same period the service command assembled 7,479 fighters that had arrived from the United States.[20] The VIII Air Force Service Command devoted a large share of its effort to this function, particularly at its main air depots.

To maintain and modify the air forces in Europe required a prodigious supply network. Unfortunately, on 1 December 1942, the supply organization of the Eighth Air Force was in a chaotic state, due primarily to the withdrawal of materiel and key supply personnel for the Twelfth Air Force in North Africa. Not only was it necessary to furnish a major portion of all available equipment to the Twelfth, but the speed at which such action was necessary also completely disrupted the organization and, particularly, the essential records of available Army Air Forces supplies in England.[21]

It was often necessary to rely on British supplies to fill operational needs. From July 1942 through June 1943, the

*Actual days when Eighth's airplanes were airborne.

General Arnold Visiting Miami Air Technical Service Command, Miami Air Depot, Miami, Florida, 10 May 1945.

Royal Air Force gave the Army Air Forces a total of one quarter of a million ship tons of materiel, half of which went for provisioning of airfields and headquarters.[22]

The Strategic Air Forces in Europe were equipped through two main organizations: The Air Service Command in Dayton, Ohio, and the Services of Supply (SOS) in the United States and Europe. The former was responsible for procuring and distributing air force peculiar supplies or those articles used only by the air forces. The Services of Supply furnished those items of equipment that were used by both the ground and air forces.

This divided responsibility presented several serious problems for the early operation and continued activity of the Strategic Air Forces. Most aviators—Knerr in particular—felt that the SOS did not adequately appreciate the fluid nature of modern air warfare, since they were geared to equip the more static ground organizations. He argued that the "fundamental fault" with the war's logistic system was the attempt by the SOS to integrate air and ground force supply systems for the provisioning of common user items: "This has meant air force dependence upon a system geared to ground force experience, requirements, and tempo of operations." As a result, the ground army failed to "appreciate and anticipate the requirements of the air war." Contrarily, "where supplies have been under Air Force control from their source in the Zone of Interior to the using unit in the theater, our supply system has proven to be completely effective." The solution, argued Knerr, rested "in providing the Air Force with a self-sufficient supply system."[23]

These arguments over the Army Air Forces' independence in operating its own supply program dominated the whole period and played a major role in the Army Air Forces' quest for independence.

On 17 April 1945, General Spaatz announced from Headquarters, US Strategic Air Forces in Europe, that the air war against Germany was over. Two years later, in his report to the Joint Chiefs of Staff, the general acknowledged the large part played by the Air Service in achieving this great success. Air Service, he wrote:

> made it possible for the planes to fly, filling their tanks with gasoline, loading them with bombs, repairing damage, and rendering the dozens of services that left airmen free to devote their full time to bombing and fighting.[24]

Air operations in Europe demonstrated, with probably greater force than ever before, the extent to which logistics factors entered into all strategic and tactical planning. The time has come, therefore, for World War II aviation historians to recognize and record these logistic factors properly.

Notes

[1] Letter to Colonel Naidall, Editor-in-Chief, *Military Review*, 5 June 1947, Spaatz Papers, Box 276, File: Papers of Hugh Knerr, Library of Congress, Manuscript Division (LCM).

[2] Spaatz, General Carl. "U.S. Strategic Air in World War II," 1947 Report to the Joint Chiefs of Staff, AFCHO, 106-90, Pt. i, Vol. 2.

[3] Letter to Commanding General, Army Air Forces, from Major General Ira Eaker, Commanding General, VIII Bomber Command, 16 September 1942, Eaker Papers, Box 16, File #104, Vol. II, LCM.

[4] *History of the VIII Air Force Service Command, 1942-1943*, Chapter I, "Mission," AFCHO 519.01, 1942-1945, Vol. 3, Chapter I. See also "Notes of Meeting on Accommodations," 28 May 1942, Eaker Papers, Box 16, LCM. See also Interview, Major General Henry Miller and Dr. Bruce Hopper, Eighth Air Force Historian, 8 October 1943, Spaatz Papers, Box 136, File: Interview Miller, H.J.F., LCM.

[5] Letter to Commanding General, Eighth Air Force, from Brigadier General Hugh Knerr, Deputy Commanding General for Administration, USSTAF, 1 March 1944, Hugh Knerr Papers, Box 3, File: Book C-5, LCM; "Notes of Interview with Major General Hugh Knerr, secretary, The Air Board," 24 November 1947, AFCHO K239.0512-616. See also Memo for Robert Lovett, from Arnold, 27 April 1942, Arnold Papers, Box 49, in which Arnold recommended that the British give Burtonwood to the Americans. See especially Letter to Arnold, from Spaatz, 5 July 1942, Arnold Papers, Box 49, File #228, LCM, in which Spaatz laid out his plans for depots and air dromes in the UK.

[6] Letter to Arnold from Ira Eaker, 30 January 1943, Arnold Papers, Box 48, File #226, LCM. See also Memo for Lieutenant Colonel Clarence McMullen, from Arnold, 19 January 1942, Arnold Papers, Box 43, File: Inspections, LCM.

[7] Commanders' Meeting, 12 October 1942, Spaatz Papers, Box 10, File: Official Diaries, Sept-Oct, 1942, LCM.

[8] Memo for Mr. Harry Hopkins, Special Assistant to the President, from Arnold, 19 May 1943, Arnold Papers, Box 123, File: SAS Cases 831-980, #872, LCM.

[9] "Air Force Supply and Maintenance," 1 January 1944, from "Report of General Eaker to the CG, ETOUSA," Eaker Papers, Box 20, File: Report of General Eaker, LCM.

[10] History of the VIII Air Force Service Command, 1942-1943, Chapter 1, "Mission," AFCHO, 519.01, 1942-1943.

[11] Draft History of the European Theatre of Operations Air Service Command, History of the Air Service Command in the ETO, Chapter V, "Materiel and Supply," 1944, Spaatz Papers, Box 293, LCM.

[12] "History of the VIII AFSC," AFCHO 519.01, 49-53. The statistical life history of a typical Eighth Air Force bomber reflected the importance of the maintenance function by showing that out of a total life of 204 days in the ETO, 68 days were spent in repair, maintenance, and modification. USSTAF, *Army Talks*. "Patterns for Air War," 17 November 1943, 2, AFCHO.

[13] Ibid.

[14] Memo, #65-6, "Procedure in Repair, Maintenance and Reclamation of Aircraft," HQS, Eighth Air Force, 15 April 1943, Spaatz Papers, Box 50, Folder: Aircraft Battle Damage and Recovery, II, LCM.

[15] Letter to Spaatz, from Eaker, 19 August 1942, Arnold Papers, Box 273; Letter, Arnold to Spaatz, 9 September 1942, Arnold Papers, Box 273, LCM; "Notes on Interview with Major General Hugh Knerr," 24 November 1947, AFCHO K239.0512-616, Box 834.

[16] Letter to Lovett, from Eaker, 9 August 1943, Eaker Papers, Box 17, "Lovett," #33, LCM.

[17] Letter to Eaker, from Albert Lodwick, Special Consultant to the War Department, 24 December 1943, Eaker Papers, Box 17, #13, LCM.

[18] Ibid.

[19] Craven, W. E. and J. L. Cate, Editors, *The Army Air Forces in World War II* (Washington, 1983), Vol. VI, "Men and Planes," p. 393.

[20] For modification, see Army Air Forces Regulation 65-15, *Supply and Maintenance, Modification of Aircraft*, 30 June 1943, Spaatz Papers, Box 57, Folder: Aircraft Modification, LCM; and Virginia G. Toole, *The Modification of Aircraft: Procedures, Policies, and Problems*, 22 May 1945, AFCHO K201-4.

[21] "History of the Air Service Command in the ETO," Chapter V, "Materiel and Supplies," Spaatz Papers, Box 273, Folder: Carl Spaatz - USSTAF Historical Section - Studies, ASC, August 1944, LCM.

[22] Ibid.

[23] Letter to Arnold, from Knerr, 10 May 1945, Arnold Papers, Box 116, File: SAS 400.

[24] Spaatz report to the Joint Chiefs of Staff.

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AFLC News Service, 20 Jan 89

Inside Logistics

Exploring the Heart of Logistics

Quality Maintenance

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The 44th Strategic Missile Wing's Maintenance Deputate is responsible for maintaining 165 remote missile launch and launch control facilities spread over 13,500 square miles in the state of South Dakota. The Minuteman II missile system deployed in the wing's facilities is one of the most maintenance intensive in the Strategic Air Command's intercontinental ballistic missile (ICBM) fleet. This is due to the age of the system and the lack of many upgrades that have been incorporated in similar systems assigned to other units. There are approximately 450 people assigned to the unit.

Under the leadership of Colonel Van Chappell, our Deputy Commander for Maintenance, the men and women of the 44th put lots of emphasis on *quality maintenance* and the team effort resulted in an annual alert rate of 99% during the last calendar year. To keep our focus on quality maintenance and to see what our deputate had to say about quality maintenance, we handed out a military letter that had only a partial line completed—"To me, quality maintenance means." We received over 20 replies that covered one or more of the following major points concerning the concept of quality maintenance:

- Follow your technical data.
- Do the job complying with all safety requirements.
- Do the job right the first time.
- Do not try to cut corners.
- Be on the lookout for better ways to do the work (work smarter not harder).
- Complete all work orders.
- Technicians, supervisors, instructors, evaluators, and staff must work as a team.
- Set and maintain high standards.
- Pay attention to details.
- Carefully and accurately document and debrief all work.
- Care for test equipment, tools, and vehicles.
- Reward work well done, and ensure accountability for work poorly done.

The letter we selected as the best overall reply was from TSgt Timothy S. Stieve:

> To me, quality maintenance means preparation, or making sure I have all the parts and tools I could possibly need to complete my dispatch without someone having to bring them out on site.
>
> To me, quality maintenance means ensuring our safety, from preparation for dispatch until we return home at the end of the day. Without safety, there would be no quality maintenance.
>
> To me, quality maintenance means assuring that my work is complete to technical order standards, so no follow-on dispatch will be required and the system works as designed if ever called to do so.
>
> To me, quality maintenance means constantly looking for a better way to accomplish my tasks, and when I do, by sharing them with my coworkers through the Technical Order Improvement System.
>
> To me, quality maintenance means evaluating myself and being my harshest critic. If I do not fail my standards, I cannot fail anyone else's.
>
> In conclusion, quality maintenance means:
>
> P - Preparing myself
> E - Ensuring safety
> A - Assuring my work is complete and correct
> C - Constantly on the lookout for a better way
> E - Evaluating myself
>
> Peace . . . is our Profession. Quality maintenance assures peace.

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SOSL Briefing to AFLMC
31 Jan 89

Software Supportability—A Quality Initiative

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Introduction

The software intensive systems of the F-16, F-15, B-1B, and ATF, and the operational problems they solve, present an increasingly complex challenge—how does the Air Force meet the growing software support requirements of these systems? Every ten years there is an order of magnitude increase in the volume of software on-board Air Force weapon systems. (9:30) In conjunction with this, software support requirements continue to increase. At the same time has come the realization that too little quality translates into unnecessary requirements for increased logistics support. An awareness of these facts has led the Air Force to define its quality initiative for not only hardware products but also software products. In general, a high-quality software system possesses such characteristics as functionality, reliability, and understandability, in addition to maintainability. The inability of users, managers, maintainers, and programmers to understand one another's concept of software quality and the inability to define and measure quality are two major contributors to user disappointments and the high cost of software maintenance.

The high cost of maintenance comes from three sources. The first is time lost in performing software maintenance rather than development. Software developers are spending too much time fixing problems identified on fielded software and not enough time devising ways to develop new software applications which possess the characteristics already mentioned. Maintenance consumes up to three quarters of the total software life-cycle cost and thus claims considerable resources that could be better used in software development. (3:81) Parts inventories and logistics infrastructure are evident in any weapons budget, but software maintenance is less visible than its hardware counterpart and threatens to undermine US security by consuming more and more defense appropriations. Edward Lublein, former director of computer software and systems at the Department of Defense (DOD), says by 1992, "Costs for developing, evolving, and maintaining defense software will have grown to become a principal factor in the determination of U.S. defense capabilities." (8:10)

Program delays are the second cost of maintenance that must be paid for due to lack of quality software. Software problems have increasingly become the most significant cause of delays in fielding modern weapon systems and supporting them once they are fielded. It is not uncommon to see one-to-two-year delays in correcting software deficiencies experienced in the field. In 1980, a front-page *Wall Street Journal* article stated: "Oil and software are the two principal obstacles to economic progress." (1:1) Eight years later that statement is still valid. Advances in software technology have not kept pace with those in hardware technology. Organizations that buy the latest computers often program in 20-year-old language with ad hoc methods far removed from the engineering discipline. This results in maintenance programmers spending between 47% and 62% of their time attempting to understand just the documentation and the logic of programs. (3:81) They are left with less than half their time to find and correct the known problem.

The third driver of high software maintenance costs is a shortage of software experts. DOD and industry are using their scarce software resources inefficiently by having to concentrate on maintenance rather than development of software. (5:11) More than a million Americans currently are developing and maintaining computer software. (8:10) The total demand for software by DOD is anticipated to increase at a rate of 12% per year for the next two decades. The supply of software professionals who can build the increasingly complex software required by DOD is expected to increase by only 4% per year. (9:30) As a result, DOD and industry can anticipate an ever-increasing shortage of software professionals.

An obvious place to start software maintenance reductions is in existing systems. The key to the software maintenance of existing systems lies in making quality modifications that will lead to easier maintenance and increased combat capability in the future. Lessons learned from software maintenance on current systems must be used in the design of future systems which will be even more software dependent.

Quality

Dr G. Taguchi, a recognized expert and leader in the quality arena, provides guidance in the approach to take in achieving high quality products—both hardware and software. Dr Taguchi's quality programs have, as an objective, improved product performance. This objective is achieved in part by knowing the needs of the customer. With these needs in mind, the designer and manufacturer set to work to produce a product to the satisfaction of the customer.

This has significant impact on the Air Force way of doing business where products are designed/manufactured according to military specification (MIL SPEC). Design compliance to MIL SPECs establishes a minimum threshold for acceptance by the government acquisition community. Compliance to MIL SPECs does not guarantee the product will be of high quality or will satisfy the needs of the Air Force customer. In the past, the Air Force has been willing to accept designs that simply meet the MIL SPEC rather than the higher quality design the contractor is capable of providing. To improve the quality of the systems developed and delivered by the Air Force Systems Command, the Commander, General Bernard P. Randolph, has committed to "put the user (customer) first." (2:2) "Putting the user first" requires a concerted effort

on the part of government and industry to examine closer the environment in which a product is used and maintained so critical support issues are identified and addressed during design and development of the product.

Blue Two Visit (BTV) Program

To ensure the software needs of Air Force customers are known to industry, Mr Lloyd Mosemann, Assistant Secretary of the Air Force for Logistics, directed the Air Force Coordinating Office for Logistics Research (AFCOLR) to provide corporate and government acquisition personnel with an in-depth look at software issues throughout the major commands. Since 1983, AFCOLR has been managing the "Blue Two Visit (BTV)" program to do just that: to expose corporate and government program managers and design engineers to "real world" Air Force operating and maintenance procedures and constraints by facilitating direct communication between these key decision planners, developers, and the day-to-day maintainers of current Air Force weapon systems. In this way, the BTV program provides an environment in which participants are influenced to design future weapon systems and support equipment to be more reliable and maintainable.

Typically a BTV lasts five days. During the five-day period, the team usually visits major command (strategic, airlift, and tactical) bases and an air logistics center (ALC). Each day starts at dawn, and the team spends a full day with maintainers in their environments. The team then travels to the next location to start again the next day. During the visits, participants are required to put in long hours on flight lines, often "suiting up" in chemical/biological/radiological gear, and performing routine maintenance tasks. Oftentimes tasks performed are on the very systems they or their company designed. Each BTV covers a particular aspect of the weapon system; for example, avionics, engines, and structures.

Software BTV

Mr Mosemann's request for a software oriented BTV was the first one to ever be conducted on that subject. Because of its complex and elusive nature, software does not lend itself easily to the "hands-on" operating and maintenance exposure typical of a hardware BTV. For this reason, a joint AFCOLR/Software Engineering Institute (SEI) fact-finding team was formed to assess the feasibility of a software oriented BTV and to determine how best to convey the messages from maintainers to software designers/developers.

The recommendations of the fact-finding team (4) resulted in a BTV to Hill AFB, Utah; Dyess AFB, Texas; and Robins AFB, Georgia. The subject of the first software BTV was built-in-test/automatic test equipment (BIT/ATE) software. Emphasis was placed on supportability, testability, standardization, MATE, ADA, documentation, retest okay (RETOK) and cannot duplicate (CND)* concerns, software modularity, hardware/software interface, and post deployment impact.

On 2 May 1988, 42 team members from 21 companies and 11 Air Force organizations departed for their first stop on a 4800-mile trip covering almost as many software issues as miles. Hill AFB was an excellent starting point for the trip, providing wide representation of F-16 BIT/ATE software issues from both software maintainers at the Ogden Air Logistics Center and software-users from the 388th Tactical Fighter Wing. BTV participants visited the F-16s and observed all three maintenance levels. The first of these was the organizational level (O-level) where BIT and technical orders (TOs) are the maintenance tool for avionics repair on the aircraft. Participants then visited the Avionics Intermediate Shop (I-level) where ATE is used to test line replaceable units (LRU) and isolate faults to the shop replaceable units (SRU). The last stop was at the depot where ATE is used to test the skills and isolate faults to the component.

The second stop was the 96th Bombardment Wing (BMW) at Dyess AFB. The 96BMW is a Strategic Air Command wing flying the B-1B bomber. The next two days provided a contrast between BIT software for a fighter and bomber as team members became familiar with the B-1B aircraft. Types of software problems from the F-16A/B to the B-1B were very similar even without discounting the significant difference in mission and age of the two types of aircraft.

The last leg of the trip concluded at Warner-Robins Air Logistics Center (WR-ALC). WR-ALC provided team members the opportunity to explore issues regarding types of weapon system software that were not part of the digital avionics software in the F-16A/B and B-1B aircraft. These software areas dealt with electronic warfare software and automatic test equipment software. At Robins AFB, members visited the facilities where development and maintenance of software for test program sets (TPS) are accomplished. The purpose of TPS is to interface particular LRUs or SRUs to ATE.

In 1987, at Hill AFB, a total of 2,492 LRUs were tested on the F-16A/B with a 33% CND rate. At Dyess AFB, the CND rate on the B-1B ranged from 75% to 90% for various systems on board the aircraft. This means that a failure is detected by BIT, but no fault can be detected by the ATE at the I-level or depot. Two factors individually or in combination account for this:

- The first of these is testing voids. Testing voids of several kinds were pointed out as real problem areas with the ATE. Sometimes O-level BIT would identify failure modes that were not tested at all by I-level or depot level ATE. In other cases, the reverse would be true. It is disruptive to the test and repair process for test voids to exist at all. When they do exist, the deficiency is accentuated and a lot of confusion is generated by the fact that different levels of tests do not always test for the same things.
- The second factor software designers and developers should realize is that, often, maintenance personnel at the O-, I-, and depot levels performing functional tests on the LRUs with the use of TOs, BIT, and ATE are not the same people and they are using different test equipment. Further, the people at O- and I-level are often at one base and the depot personnel at another. This results in ambiguous and confusing test measurements with various levels of BIT and ATE not agreeing on the presence of a problem. The situation is difficult enough to overcome with one person performing all the tests, but it is doubly compounded by different individuals at different places trying to explain why they failed a test in one place and passed the same test in another place. Where the same software test is required at different maintenance levels, the same criteria should be used; that is, a persistent progression of tolerances.

*The organizations visited used the terms RETOK and CND interchangeably. To eliminate confusion, CND will be used throughout the remainder of this paper.

The key message from the BTV was the need for "vertical testability." Many of the fault isolation and CND problems were attributed to incompatibility between the information provided by BIT at the O-level, ATE at the I-level, and ATE at the depot. These systems are independently developed and are not designed so that failure "X" means the same thing for each level of test. Therefore, the fault detection/isolation process has been and continues to be started from scratch at each level of maintenance.

In light of these deficiencies, maintenance personnel need more technical data describing BIT and ATE hardware and software. Documentation supplied by the contractor is not detailed enough to allow an operator at I- and depot level to investigate the reasons behind the problems. Higher Air Force organizational levels do not realize the necessity for detailed technical data and resist its procurement as an unnecessary expense. This puts a tremendous load on the Air Force Logistics Command (AFLC) to provide unnecessary spares, training, and hardware and software oriented manpower. The problem is enormous because of the multitude of systems and subsystems the Air Force owns and maintains. This was most visible at Robins AFB where maintenance must be addressed on 175 separate operating ATE test sets. If maintenance personnel had access to schematics and notes, they could tell exactly why a test failed and what types of voltages and signals were expected at certain points. This would enable the tester to perform some manual tests which could further isolate problems and expedite the repair process.

The BIT features in each LRU need to be described in greater detail in the general systems TO. This detail should provide maintenance personnel with information on what BIT is checking at each and every step. With this knowledge, maintenance can logically isolate a malfunction. Until a BIT is developed and proven effective, the technicians need to have the system data available to them in order to correct all malfunctions effectively the first time. The alternative has been to change an LRU and hope they guessed right—"swaptronics."

It should be noted that the aircraft maintenance units for the F-16A/B had a 99% fix rate in peacetime conditions. In wartime conditions, this rate is predicted to decrease due to a shortage of time to isolate the problem. Better LRU fault isolation is needed to reduce LRU ambiguity groups and allow pulling the right box the first time. When BIT, ATE, and TOs fail to isolate software/hardware problems, maintenance personnel are left with only one alternative—"swaptronics." The ramifications of this maintenance nightmare are:

(1) Decreased combat capability—it takes many man-hours and lost sorties to isolate and correct the problem.

(2) Increased maintenance manpower at all organizational, intermediate, and depot levels.

(3) Increased spares costs for additional LRUs needed to fill the pipeline when LRUs are backlogged in the avionics intermediate shop (AIS) and depot waiting for identification of a problem that may or may not exist.

Issues Raised on BIT/ATE Software Support

One observation made by a BTV member after five days of discussions concerning Air Force software support was: "Just as program managers tend to overlook support hardware and place mission equipment first, the same thing is going on in support and mission software." This was particularly apparent when ATE software changes were submitted as software deficient reports (SDRs) and it took 12-24 months before the software was modified. Not only is priority lacking on timely software maintenance but also in software design. BIT/ATE software development by industry and the Air Force does not include input from maintainers. It is the maintenance personnel who have first-hand experience with the software. **Valuable insight into future design of software is missed when depot and unit maintenance personnel input is overlooked or not given the priority it deserves.**

Another example of the low priority given to software is that as modifications are made to the avionics LRUs, the self-test features are eliminated to provide additional room for performance modifications. In the cases where new capabilities and additions are made to the operational system, BIT and ATE are not upgraded.

It is not just sharing ideas that is conveyed on BTVs. It is also a sense of frustration experienced by BTV participants as they find out for themselves the difficulty of performing maintenance tasks with software characterized as poorly documented, unreliable, and outdated. This feeling is further reinforced in BTV participants during conversations with Air Force maintainers who are frustrated that they cannot do a better job because of limitations imposed by the fielded aircraft design. Along with the frustration is a strong motivation for AF maintainers to overcome the limitations "one way or another." The procedure "one way or another" must become the motivation for the DOD and industry acquisition communities to design a weapon system that is maintained "one way" because it was designed to be reliable, maintainable, and of high quality at each step of "the way."

Conclusion

Inclement weather, long hours, lack of spare parts, and use of special support gear highlight to industry the day-to-day constraints of maintenance and the necessity for future reliable and maintainable weapon system components and support structures. In the software environment, the "constraints" are largely due to the combination of technical and management variables which are in place as a result of the system—the way the Air Force currently does business. Software constraints can **be lessened if not eliminated. The fact that the air logistics centers do not have adequate computer support and support tools is not a "real world" limitation like the freezing weather in Minot, North Dakota, or maintaining an aircraft while in chemical/biological/radiological gear. Much can be done to improve the software support requirements of Air Force weapon systems. It is through sharing ideas and experiences that the Air Force and industry will build the next generation of weapon systems which are supportable from the maintainer's perspective.**

As the military environment and priorities change so too does the BTV program. On future BTVs, software as well as hardware issues will be demonstrated and discussed. Future BTV schedules will include at least one trip which deals specifically with weapon system software. The BTV program schedule has been set for 1989 with participation open to DOD and industry personnel. An electronic warfare software BTV is scheduled from 12-16 June 1989. This trip will follow the EW software cycle from the Tactical Air Warfare Center through the EW Software Support Center to an operational field unit.

Continued on page 28 ▶

Long-Range Management Information System Planning: A Case Study

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Introduction

The purpose of this article is to describe the development of the first Air Force Contract Management Division (AFCMD) five-year Acquisition Management Information System (AMIS) implementation plan. The plan was developed by the AFCMD AMIS support office in the Directorate of Contract Administration. The Acquisition Management Information System is the Air Force Systems Command (AFSC) implementation of the Department of Defense Directive for Military Standard Contract Administration Procedures (MILSCAP). The system functions as a corporate information and central procurement disbursement system. It is centrally maintained and controlled by the AMIS Systems Program Office (SPO) at Wright-Patterson AFB, Ohio, and locally implemented by each of the major AFSC product buying divisions and AFCMD. We will discuss the AMIS CONTRACT database which contains data on contracts: (1) administered and paid by AFCMD, (2) paid but not administered by AFCMD, and (3) AFCMD administer-only contracts. The overall goal of the five-year plan was to provide AFCMD AMIS users quality automation tools in support of their contract administration and surveillance functions at 25 geographically dispersed field locations known as Air Force Plant Representative Offices (AFPRO). This article is based on the author's experiences as the AFCMD AMIS manager.

In addition to its function as a contract payment system, AMIS performs key management information system (MIS) applications for AFCMD contract administration personnel, such as maintaining a record of spare parts pricing history, tracking unpriced contract actions (UCAs), and providing an accounting of appropriated monies to the contracting and financial communities.

Purpose of Plan

The purpose of the AFCMD five-year AMIS implementation plan was to provide a strategic direction for AMIS initiatives and ensure automation-related resources were directed toward high payoff mission-essential functions in the contracting functional area. The plan was intended to be a vehicle to get AMIS to meet AFCMD data requirements. These requirements would then be included in the overall AFSC AMIS effort. The plan was also intended to ensure quality logistics support to AFCMD headquarters and to the AFPROs for all AMIS applications. The intent of these automation tools was to improve productivity of the contract administration function and leverage resources. Productivity was a significant issue since "contracting workload continues to increase, yet manning levels do not."[1] The five-year plan was written to ensure it complemented the overall AFCMD corporate and MIS plans.

Other purposes of the plan were to stimulate innovation, ensure orderly growth of AMIS applications, and prevent duplicate development of automation tools. The plan helped ensure user and mission requirements drove the system design rather than technology. One of the most important concerns addressed was ensuring AMIS applications did not exceed the resources required to support them logistically. The overriding philosophy was to automate only high payoff functions since there were not enough resources to automate every task. This philosophy helped avoid a common pitfall experienced by other organizations: taking on too many initiatives at once.

Problems

The five-year AMIS implementation plan for AFCMD was designed to improve several deficient conditions with the current system and to incorporate new technologies. In order to be successful, systemic problems needed to be identified and corrected. The approach was to develop the system as modules.

The major problem experienced by field users had been a lack of confidence in the accuracy and timeliness of AMIS data and a limited ability to correct these deficiencies. Poor data quality discouraged use of the system and lack of user activity contributed to poor data quality. The majority of data input was done at AFCMD headquarters by procurement clerks assigned to the comptroller. As a result, data input and correction responsibilities were not always in the same office. It was difficult for comptroller personnel to maintain data accuracy and timeliness, given the large volume of data to be input and the poor quality of contractual source documents. AFPRO and comptroller personnel regularly received late copies of contract documents for input into AMIS. This affected their ability to maintain data timeliness and accuracy. The data quality problem was also aggravated by high turnover in data input clerks at AFCMD headquarters and at the AFPROs. Thus, the lack of field user confidence in the management data and their limited ability to correct it led to the development of alternative local personal computer (PC)-based systems for AFPROs. For example, AFCMD used an AFPRO-wide system to track UCAs, known as tracking undefinitized requirements and funds (TURF), even though AMIS had a similar UCA system. AFPROs also developed local PC-based systems to track spare parts pricing actions.

Besides the duplication of data input and alternative systems development efforts, poor data quality created additional, unproductive workload since AFPROs had to manually reconcile their local system's data with AMIS; e.g., reconciliation of TURF and AMIS UCA data. The extra effort spent with reconciliation and status tracking detracted from the completion of their primary duties of contract administration.

Another serious problem was poor computer-to-computer communications since the system directed use of voice instead of data lines. Communications were frequently degraded due to line noise and over-saturated telephone lines. Inputting accurate and timely data was difficult and caused significant AFPRO user frustration.

All these situations resulted in AMIS not living up to its potential and AFCMD not effectively leveraging its automation resources to improve productivity. Many functions were still being done by tedious and labor-intensive processes. Scarce resources were used in developing and supporting alternative automated software applications at separate field offices. Van Scotter notes the significance of this problem:

> Duplication of effort and lack of standardization also cause problems. It is not productive for ten different units to develop ten different versions of the same report. If that happens, the Air Force has invested ten times the man-hours it should have taken to develop the program. Also, we probably have ten programs incompatible with each other.[2]

Concept Development

Thus, long-term AMIS direction was essentially required to ensure quality automation tools were available to support AFPRO contract administration functions. The time period covered by the AFCMD AMIS implementation plan was 1987 to 1991. A five-year time frame was believed to be the maximum feasible planning horizon, given anticipated changes to mission requirements and computer technology. The scope of the plan was limited to government-developed applications software; commercial products were not considered. The essence of the plan was to provide tools to help administrative contracting officers (ACOs) at 25 field locations perform their functions and to convince top AFCMD management to provide continued resources and support.

The plan was developed by looking at three alternatives: (1) expanding AMIS applications for AFPROs, (2) keeping AMIS at its present level, and (3) reducing AMIS applications. Given the limited AFCMD support infrastructure, it was decided expansion of AMIS applications would be logistically unfeasible; therefore, the first option was rejected. Option three was not implemented because of the acute AFPRO need for automation tools to support the contract administration function. Option two was selected since it was the only viable alternative; the plan was to substitute each current module with an improved version. A time-phased implementation was used to introduce the separate but interrelated application modules. Additional software applications (beyond the one-for-one substitution) would be added in the out-years as the support infrastructure grew.

The five-year strategic plan did not specify detailed events and schedules. Rather it set general goals, timetables, and priorities. The plan was to serve as a guide for AFCMD corporate and local AFPRO AMIS implementation efforts. The broad strategic plan was to be supplemented by tactical plans. The tactical plans would contain detailed technical and schedule instructions for implementing each module of the strategic plan.

Primary Elements of Plan

The first item of business was to ensure the number of AMIS applications remained at a supportable level. Information processing requirements and support capabilities needed to be matched to promote long-term success. A common pitfall in automation planning is to develop too many concurrent initiatives.

The first major part of the plan was to make improved data accuracy the number one priority. AMIS usefulness was contingent on data accuracy and timeliness. The need to establish a system of checks and balances to maintain ongoing data quality was essential. Previous data cleanup efforts, referred to as "baselining," had been largely unsuccessful because the continuous receipt of inaccurate new data served to move the system out of balance after a short period.

Initiatives to increase automated data exchanges as a means to improve data accuracy, efficiency, and timeliness were adopted. Automated data exchanges would save on redundant input effort and reduce the errors normally introduced by manually transcribing data from hardcopy contract documents into AMIS. Automated data exchanges were also viewed as vital to solving problems with lost or late source documents which were manually input into AMIS too late to be useful. The five-year plan intended to continue and expand the existing efforts of the comptroller's data exchange initiatives. The key candidates for automated data exchanges were the information systems of other government agencies and contractors with the most volume of data to be transferred. Data exchanges with the highest payoff were to be considered first, such as the Air Force Logistics Command (AFLC) D220 system with its voluminous provisioned item order data, contractor invoices, contractor-priced support and spare parts lists, and DD250 delivery data. Other exchanges were selected based on their ease of implementation.

Built-in data edits were incorporated into application software modules as a first line of defense to reduce erroneous data entry. For example, only a proper 13- or 17-digit contract number could be entered in the TURF input procedures. An additional feature of using defaults to carry over "boilerplate" data for related contract documents was added.

To encourage AFPRO use of AMIS and increase data accuracy, an effort was started to allow AFPRO users to input data on "administer-only" contracts. A key restriction prohibited AFPROs from changing accounting or contract payment data when the comptroller paid the contractor. Control of this data would continue to be centrally maintained by the AFCMD comptroller. This proved to be a difficult problem since some of the accounting and management data overlapped, such as obligated dollar amounts.

To improve data quality, statistical quality control and audits of critical data elements were required. Previously, there was no regular statistical analysis of AFCMD-related AMIS data. The remedy was for statistical analysis to be accomplished on a regular basis by independent sampling of AMIS data from AFCMD headquarters and field offices. The goal was to improve data accuracy by identifying deficiency trends and root problems. Automated sampling and data analysis were considered essential. The key to automated sampling would be to identify and flag outlying data points. It

was necessary to measure error rates to quantify results of the data corrections. Automated processing of data quality control would help ensure the control mechanism matched the complexity of the system. Automated quality control would also be applied to inputs received from automated data exchanges. Even with automated checks, the sheer volume of data required selective sampling. As a result of the large volume of data in AMIS and the high cost of quality control, it was decided to focus on maintaining the accuracy of selected critical data elements to reduce costs. Use of computer-generated reject listings to identify data inconsistencies for each AFPRO proved invaluable.

Data quality was also adversely impacted by poor quality source documents received from other agencies. For example, some documents contained a five-positioned contract line item number (CLIN) instead of the standard of four-positioned CLIN. These anomalies frustrated efforts to maintain an accurate database and also adversely impacted automated exchange efforts since computers need exact formats for data transfer.

The second major part of the five-year plan was to include other initiatives such as an improved price history database (PHDB) for spare parts pricing, improved unpriced contract action tracking system, introduction of electronic scanner-based abstracting (data input), and implementation of improved contract writing/document preparation software.

The PHDB provided a shared, centralized repository of AFPRO spare parts pricing and value review data. Its purpose was to prevent future "horror stories" on overpriced spare parts for weapon systems. The improved PHDB involved redesigning the database to speed up retrieval of information, improve output reports, and maximize off-line data capture and transmission capabilities. To improve the utility of the PHDB further, it was proposed to design more flexibility into the PHDB by use of local and corporate data elements. The local data elements (LDEs) could be created locally and would not be transmitted to the AMIS mainframe for storage in the centralized database. LDEs were required due to the unique spare parts pricing situation at each AFPRO.

The improved unpriced contractual action tracking and reporting system was called tracking undefinitized requirements and funds for AFPROs (TURFA). This system was designed to track UCAs where the AFPRO ACO was responsible for obtaining a firm (definitized) price. TURFA also performed optional UCA funds tracking for the AFPRO and combined the local AFCMD UCA tracking system and the centralized AMIS UCA system. The result was improved productivity since a 36% duplicate data input was eliminated. This also created a single, consistent database for AFCMD UCA reporting to Congress. This single database was an important benefit since the previous manual reconciliation of UCA data between the local and central system (for reporting purposes) created additional workload. The manual reconciliation detracted from completion of UCA definitization.

The next initiative addressed by the plan was electronic scanner-based abstracting. The purpose of electronic abstracting was to improve data input timeliness and accuracy for direct entry of the large volume of hardcopy contract documents into AMIS where automated data exchanges were not established. The eventual goal was to provide AFPROs with this capability when the per unit cost of the scanners decreased to a more affordable level. Electronic abstracting has the potential to improve productivity by reducing clerical input effort, improve accuracy, and improve data input timeliness. At the start of the plan, technology was not available for electronic abstracting to be performed on a cost-effective basis. However, it was anticipated this technology would be available in the near future.

The last key application addressed was improved contract writing software for AFPROs. The goal of this initiative was to combine word and data processing functions. The intent was to use a formless, menu-driven approach saving on data input and reducing the volume of contract documents. The current source data automation (SDA) was an inefficient forms-driven process. The improved system would also allow more extensive off-line edits. The goal of this effort was to increase productivity and transfer more AMIS data accountability and control to the AFPROs. The improved contract writing process would replace the current SDA process. The initiative to introduce improved contract writing software for AFPROs depended on upgrading PC working memory. Based on the increased capability of the Zenith 248, these terminals were targeted to incorporate the new software writing function when they became available in sufficient quantities.

Field tests of application software at selected AFPROs were required prior to overall AFCMD implementation; this proved to be an effective risk management technique and increased user acceptance. In addition to serving as a quality control mechanism, field tests provided important data on long-term support requirements of the particular application being tested. Another key part of our effort to bolster the support infrastructure was to improve and institutionalize user training programs. To this end, each subsequent AMIS module for AFPRO use was to have a separate and stand-alone user guide. Each user guide would contain detailed, step-by-step instructions. The use of computer-assisted instruction was also expanded.

The goal of efforts to expand off-line data capture and transmission capabilities was to reduce life cycle costs with respect to telecommunications. This meant data files would be created off-line (at the AFPRO) and then transmitted to the AMIS mainframe when completed. Off-line data capture and transmission offered improved data quality due to reduced exposure to line noise. Users were also more satisfied since system response time improved considerably. Use of the off-line system allowed for faster response to database queries since mainframe processing time was not taken up with lengthy, on-line data inputs. Another advantage of the off-line method was the ability to retransmit a data file if a communications interruption occurred. The on-line method would have required a complete reinput of all lost data. The off-line capability allowed the AFPRO to perform essential functions, such as preparing a data file for transmission, even while the mainframe was inoperable.

Concerns

Some concerns affected AFCMD's ability to implement this plan and contributed to the risk and uncertainty. One of the major obstacles was resistance to change. Many AFPRO contract managers were concerned about using an AFCMD-wide MIS which allowed detailed and instantaneous visibility of their management operations. They were also concerned about the system being used to micromanage their affairs. Another major problem to overcome was the lack of enthusiasm for AMIS. Many AFPRO commanders and ACOs

had experienced problems with the original AMIS during their careers and viewed the system as a drain on local operations since much of the data went for higher headquarters reporting instead of meeting local needs. AFPRO people were also disillusioned about their limited ability to change erroneous data.

Other concerns affecting the success of the plan were the logistics of supporting AFCMD AMIS training and operations on two types of PC workstations. The standard AFPRO IBM PC workstations were gradually being replaced by Zenith 248s. This situation complicated the logistics of user support and required extra troubleshooting and training. The implementation schedule for the Defense Data Network (DDN) was also a concern since DDN promised to improve computer-to-computer communications significantly. Given the uncertainty caused by the continuing DDN delays, it was decided to implement the plan without DDN, but add it when it became available.

A large part of the success of the five-year plan depended on maintaining the support of top AFCMD management. Top management could provide necessary monetary and personnel resources essential to continued success. To maintain interest, the plan needed to be kept at the forefront of management's mind by frequent progress briefs.

Control of the plan was essential. To ensure effective control, quarterly reviews were established to determine if the plan's major objectives were being met; requirements were also revalidated. These frequent reviews were necessary, given the dynamic nature of the AFCMD mission and computer technology. Another key factor affecting control was the difficulty with determining how to specifically measure progress of the overall plan.

Conclusion

Planning is essential for efficient and effective MIS implementation. Strategic MIS planning is a difficult task since it is a cognitive process; asks people to take risks; forces the acknowledgment of uncertainty; asks managers to commit to a specific course of action; and focuses on long-term, esoteric goals versus short-term, tangible results. Planning may create problems with goal conflicts since many different departments are involved. Planning is also complicated by varying MIS user requirements. As a practical matter, it is difficult, if not impossible, to design a "one size fits all" type of MIS. This was initially the case with AMIS for AFCMD. Managers can help ensure success of strategic MIS initiatives by designing flexibility into a system such as local data elements for spare parts pricing. A key aspect of planning is to determine upfront as many requirements as possible. Use of a work breakdown structure (WBS) methodology greatly helps with structuring requirements. The WBS also serves as a basis of use of quantitative tools to allow better evaluation of the respective payoff of alternatives. Contingency plans should be made to ensure continued coverage should a new automation initiative not work.

The most effective way to structure a strategic MIS plan is to use the "systems approach." This was done by the AFCMD AMIS support office to identify and evaluate the interrelation of each element of the system. The systems approach also allows for recognition of any positive or negative synergy. A basic tenet in the systems approach is to ensure the understanding of the cumulative logistics effect of trying to support all application software modules. Each new application brings a new level of overhead. This overhead requirement, in turn, reduces the ability to develop and implement new systems unless more support resources are obtained.

Modular development and implementation of each part of the system is a good risk management technique. Development of each module should require a detailed cost-benefit analysis, an analysis or work/information flow, and an estimate of life cycle cost requirements. Managers should be sure the automated system complements manual processes and supports corporate goals. Managers should also realize it is not cost effective to automate every function.

Information system plans should be tiered with respect to their planning horizons. The strategic plan should state general goals and timetables and should be supported by detailed tactical (middle-term) and operational (near-term) plans. The time horizon for a strategic plan is normally three to five years. A tactical plan should span one to three years. An operational plan usually spans one year or less. Each new module should have its own separate tactical and operation plans. It is absolutely essential to support all implemented applications adequately. Planning helps ensure this occurs.

It is still too early to evaluate the overall effectiveness of the AFCMD five-year AMIS implementation plan. It is important to realize planning is not a panacea, a substitute for action, or an end unto itself. Planning allows managers to be proactive instead of reactive. The plan is merely a vehicle to achieve a stated objective. Planning requires discipline. One of the biggest mistakes managers make with respect to MIS planning is to rush off in a haphazard fashion to incorporate each and every new computer application without considering life cycle cost and support requirements.

Notes

[1]Cook, Curtis R. "The Acquisition Management Information System—Friend or Foe?" Proceedings of the 1983 Federal Acquisition Research Symposium, pp. 23-27.

[2]Van Scotter, James R. "User-Developed Software for Air Force Microcomputers," *Air Force Journal of Logistics*, Vol. X, No. 2, pp. 22-24, Spring 1986.

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References

1. Bulkeley, W. M. "Computer Makers Feel Key to Sales Edge Lies in Better Programming," *Wall Street Journal*, 29 September 1980, pp. 1, 18.

2. Department of the Air Force. AFSCR 550-12. *Reliability, Maintainability, Producibility Commander's Policies*. Andrews AFB DC, 15 April 1988.

3. Hall, Rand P. "Seven Ways to Cut Software Maintenance Costs," *Datamation*, 15 July 1987, pp. 81-84.

4. Hefley, William E. et al. *Issues in Software: A Blue Two Visit Feasibility Assessment*. Technical Report CMU/SEI-87-TR-42, January 1988.

5. "Industry Observer," *Aviation Week and Space Technology*, 11 July 1988, p. 11.

6. "Logistics 2010 - Strategies for the Future," DOD Logistics Strategic Planning Guidance, April 1988.

7. Martin, James, and McClure, Carma. *Software Maintenance: The Problem and Its Solutions*, New Jersey: Prentice-Hall, Inc., 1983.

8. Roy, Daniel M., and Jaworski, Allan. "Birth of a Programming Language," *Aerospace America*, July 1988, pp. 10-14.

9. Smith, Maj Gen Monroe T. "Project Boldstroke: A Plan to Cap a Software Crisis," *Government Executive*, January 1987, pp. 29-30.

Electronic Data Interchange: A Comparative Analysis of Government and Industry

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The use of electronic data interchange (EDI) is fast becoming the norm for logistics transactions. This is true in government as well as in industry. This paper examines the differences and similarities in EDI usage, benefits, and implementation between industry and government.

Background

Electronic data interchange (EDI) is the computer-to-computer transfer of standard business documentation in machine readable form. The objective of EDI is to allow for business information which is transmitted by the sender to be directly acted upon and processed by the receiver without the need for re-entry into the receiver's computer system.

There are three basic ways in which EDI can be conducted: terminal to computer, computer-to-computer direct, and computer-to-computer through a third part or value added network. (2, 16) A terminal to computer network places a data entry terminal from one company (a supplier) in an office of a second company (a buyer). These networks are usually private and proprietary systems which allow for communication only between specific companies. To expand the network, additional terminals must be used. Further, the sender of the information must provide the information in the format specified by the receiver.

Direct computer-to-computer systems involve the linkage of one company's computer directly to a second company's computer. This type of network is practical when companies conduct a large volume of business with each other. This system requires that both companies use the same data formats and the same communication protocols. In addition, the computer hardware must be compatible.

The third EDI option, and the one which appears to be the fastest growing, is that of computer-to-computer links through a third party or value added network. Under this system, a company establishes an electronic link with a communications network. The company is then able to communicate and to transmit business documentation with any other company using the same network. In addition, the network will also translate data from one format to another, thereby providing a way for companies to communicate even if they are using different formats or standards.

What is EDI Used For?

Electronic data interchange is appropriate for any business documentation or information which can be described as a standard format; however, currently EDI is used primarily in two areas: purchasing and transportation. (While electronic transmission is also used extensively to transfer funds, this is most commonly referred to as electronic funds transfer (EFT) and will not be included in this discussion of EDI.)

Because of the very high level of transactions, and thus paperwork, involved in both purchasing and transportation, the use of EDI in these areas is likely to yield substantial results. In the purchasing areas, the use of EDI is most common for the transmission of purchase orders and invoices. Common formats and standards for these documents have been established in a number of major industries. In addition, the government is also using EDI for the transmission of purchase orders and invoices. (1, 6, 7)

The same is true on the transportation side. The most common transportation documents which are transmitted electronically are the bill of lading and freight bills. The use of EDI actually started in this field with the development in the late sixties of the first standards for electronic transmission of transportation documentation. While it was almost 15 years after the publication of the original standards that the use of EDI in transportation really started to grow, EDI in this industry is now commonplace. (8, 16) There are presently over 200 transaction sets which have been standardized and are available for either purchasing or transportation documentation. (10)

Industry Usage of EDI

The total percentage of transactions being transmitted electronically is still very small. A recent study estimates that 7% of all customer initiated transactions are transmitted electronically. (14) However, EDI usage is pervasive across all industries. Further, in selected industries, EDI usage is substantial for purchasing and transportation documentation.

EDI in Transportation

According to *Distribution Magazine,* "EDI is now becoming the modus operandi of the transportation business." (8:36)

A recent survey of the National Industrial Transportation League shows that well over 100 member companies are using EDI and that the number is steadily increasing. Nearly all major carriers in all modes have either already implemented EDI to some extent or have EDI implementation efforts underway. A sampling of carriers using EDI includes PIE Nationwide, Leaseway, and ANR Freight in the trucking industry, American Airlines in the air industry, and Southern Pacific and Burlington Northern in the rail industry. Further, the Association of American Railroads has established RAILINC, its own EDI network. (8)

EDI in Purchasing

Current usage of EDI for the communication of purchasing documentation is also becoming significant. EDI is presently being used by both manufacturers and by merchandisers for the transmission and receipt of purchase orders and invoices. For instance, significant industry efforts are underway by major manufacturers in such industries as automotive, electronic, and chemical. The same holds true in merchandising where substantial EDI usage can be found in the grocery, retail, and wholesale drug industries, and in warehousing. (6, 8, 9, 23)

Government Usage of EDI

The government usage of EDI, while somewhat less in volume than industry usage, parallels that of industry. As in industry, EDI is being used for both transportation and purchasing transactions. On the purchasing side, EDI in the government is being used both for purchases made for resale (merchandising) and purchases made for internal government use (''manufacturing'').

EDI in Transportation

As the largest shipper in the world, the Department of Defense has an interest in improving and streamlining the transportation process, and is looking toward EDI as a measure to accomplish the streamlining task. (12) The DOD recently completed an EDI pilot test of electronic transmission of the Government Bill of Lading (GBL). Twelve DOD activities, three motor carriers, and three finance offices were involved in the test. According to Ken Stromberg of the Office of the Secretary of Defense for Transportation Policy, the test showed that EDI reduced costs and paperwork. The near term plans within DOD for use of EDI on the transportation side are to increase the number of DOD activities using EDI to transmit the GBL. Long-term plans call for the expansion of EDI to include other transportation documentation. (21)

Currently, DOD is working with national standards associations to develop compatible government and industry wide standards and transaction sets. Through EDI, DOD hopes to reduce the paperwork generated by the over 1.4 million bills of lading issued annually by DOD. (8)

EDI in Purchasing

On the purchasing side, the government has started major EDI efforts on goods purchased for resale. Commissaries and exchanges (similar to grocery stores and department stores) are transmitting purchase orders using the industry format for the grocery industry (UCS). DOD has obtained one UCS identification number for use by all the military stores. According to a trade group which represents manufacturers who sell to the military stores, ''Each service has found that EDI is the way to go.'' (15:5) However, the services are on different implementation schedules.

One organization which has already implemented EDI is the Army and Air Force Exchange Service (AAFES). Currently, AAFES is transmitting approximately 300 purchase orders a week to about 12 vendors through EDI. (24) Another organization which is using EDI is the United States Marine Corps Commissary and Exchange System. The Marine exchanges are currently transmitting purchase orders to vendors, while the commissaries are in the implementation stage. (15)

Currently, the documents which are being transferred electronically are limited to purchase orders; however, efforts are underway to include additional documentation. The C. Lloyd Johnson Co., Inc., now electronically exchanges purchase orders with both AAFES and the Marine Corps. The Johnson Company is a broker receiving orders from the military and then transmitting the orders to food manufacturers. The company is currently working on an effort to have orders move directly from the military to the manufacturer, to then have a shopping notice sent to Johnson, and then to have an invoice sent directly to the military. (5)

The government is also beginning to use EDI in the purchase of goods for internal use by the government (as opposed to goods for resale). The General Services Administration (GSA) is currently working on EDI implementation and regulations. So is DOD who may, according to some sources, require EDI capability from the majority of its 300,000 suppliers. (9) Also using EDI is the Federal Supply Service (FSS). According to Ralph Hostetter, the FSS has been involved using various forms of electronic transfer of purchase orders for four years. Currently, the FSS fully supports the use of the ANSI X.12 Standard as the format for EDI transmissions and is working to increase the use of EDI. (13) The Defense Logistics Agency (DLA) is also heavily committed to EDI. The DLA is currently using a Paperless Ordering Purchasing System (POPS) with a number of vendors and has EDI efforts underway in the purchasing and invoicing area. (18)

An example of an EDI effort underway in the DOD is the MAGIC system. MAGIC, Manufacturers and Government Interconnected by Computers, electronically links defense contractors with Air Force buying offices. Currently, MAGIC is in the prototype stage and is being tested at Ogden Air Logistics Center. The objective of the MAGIC system is to eliminate the paper form of purchase documentation, both within the government (purchase requests) and between the government and contractors (purchase orders). Thus far, the MAGIC system is transmitting internal documents electronically, with transmission of purchase orders to contractors under test. (17)

Reasons for Use of EDI

The benefits of EDI are now widely recognized and accepted. Benefits commonly cited by users include reduced paperwork, reduced errors, reduced order cycle time leading to reduced inventory levels, increased productivity, and access to better and more timely information. (1,6,8,9) While these benefits accrue to any organization using EDI, the relative value of the benefits appears to differ between industry and government applications.

Critical Benefits to Industry

The most critical benefit of EDI implementation to industry users is not cost reduction, but rather service improvement. While costs are an important concern, they are not the critical factor. According to Professor B. J. LaLonde of The Ohio State University, ''It is clear that the environment of the logistics executive is changing. The traditional concern with costs . . . has broken down and the executive's concern is more clearly identified as a strategic one.'' (1:48) This strategic concern is of significance in the use of EDI.

According to *Network World,* the most important factor influencing industry to use EDI is a "strategic imperative." (19:21) David Carlson, Vice President of Corporate Information Systems for K-Mart, has stated that industry usage of EDI is increasing because EDI is "pro-competitive." (1:51) He further stated that "EDI frees the company from so many . . . bonds and is a liberating concept and really improves competitive positioning." (1:53)

According to the Yankee Group, EDI is "a basic way of changing how America does business . . . and is spreading from a few hardcore industries such as grocery, hardware, and pharmaceuticals to dozens of others." (3:80) As the use of EDI has spread, many companies have found that they have been forced by competitive pressure to use EDI.

Tom Rush of Coopers and Lybrand believes that EDI is becoming the only logical business option for companies operating in a Just-in-Time environment which calls for frequent and small orders. (19) In addition, many companies have found that their major customers are demanding the use of EDI. According to *Information Week,* EDI's "momentum may be unstoppable in paper products, metals, oil and gas, chemicals, grocery, office products, warehousing, rails, trucking, ocean freight, pharmaceuticals, and medical supplies." (9:23) A recent study of industrial suppliers showed that over 61% had been strongly requested by major customers to implement EDI. (14)

It appears then that industry sees EDI primarily as a tool to gain competitive advantage, and as a tool which is quickly becoming a necessity from strategic standpoint. However, the same does not appear to hold on the government side.

Critical Benefits to Government

On the government side, where competitive forces are not as strong, the critical reason for using EDI appears to be for cost reduction and productivity improvement. This focus is reflected in a recent *EDI Executive* article which stated that "Commissaries and exchanges run by various branches of the US military are using EDI to fight the battle of rising cost." (15:5) According to William Wallace of AAFES, the major benefit of EDI is a reduction in administrative time which leads to a reduction in order processing time. The order processing time reduction has allowed for a 5- to 6-day reduction in safety stock, thus reducing inventory costs. (24) On the transportation side, DOD has stated that it hopes to save between $10 million and $17 million annually through the use of electronic bills of lading in lieu of paper bills of lading. (8)

Although cost reduction appears to be the most critical reason for EDI usage in the government, it is not the only reason. As in industry, the government is using EDI to improve service. For instance, the current use of EDI in exchanges has allowed military stores to order directly from suppliers rather than going through central warehouses. The direct ordering has resulted in faster receipt of seasonal and fashion merchandise, thus improving both service to customers and sales. (15) Further, according to Jack Bartley of the Office of the Secretary of Defense, EDI "supports a commitment to improve interoperability, increase productivity and move toward a paperless environment." (4)

Implementation Issues

Any organization which implements an EDI system faces challenges. Even though EDI is becoming commonplace, the decision and process to implement such a system is still not an easy one. According to Richard Norris of Arthur D. Little, Inc., implementing EDI is "not something where you turn on the switch. It is a long hard slog." (3:82) Typical problems faced with EDI implementation include resistance to change, the need to upgrade and/or change internal procedures, the integration of EDI with existing systems, and legal and accounting concerns. (1, 9, 11, 19) While these challenges face any user of EDI, in some instances the obstacles to EDI are stronger in government applications.

Implementation Issues Unique to Government Applications

The use of EDI often requires modification of internal systems and a change in procedures (changes in copies filed, signatures obtained, etc.). While implementing such changes can be a challenge in any organization, making the changes in a government environment may often prove even more difficult. Often government procedures are based upon law and regulation rather than being based just upon company policy, and therefore are difficult and time consuming to change. For instance, according to the designers of the MAGIC system, "As data processing speed wipes away days and weeks of administrative processing time, time constraints imposed by the Federal Acquisition Regulation and other legislative constraints become far more prominent." (17:213) According to Ken Stromberg of OSD, many federal regulations do not provide for doing business electronically and must be changed. (21)

Policies governing vendor selection are also a problem in government implementation of EDI. In industry, the trend in both purchasing and transportation has been toward a reduction in the number of suppliers (vendors or carriers). The reduction in the number of suppliers allows for longer term contracts and a closer relationship between the parties. The reduction in the supplier base also eases EDI implementation since it reduces the number of trading partners involved. However, in both government purchasing and government transportation, vendor selection is often governed by policies intended to increase competition and to make government contracts available to a large number of suppliers. According to Roy Saltman of the National Bureau of Standards, current laws will not allow the government to refuse to do business with vendors who do not have EDI. Further, while it is the government's intention that EDI will become the normal way of doing business with the government, the government cannot force suppliers to use EDI. (20)

Another challenge unique to the government is the integration of EDI with existing systems. While any organization implementing EDI must integrate EDI with internal computer systems, the government, more so than industry, tends to have complex communication systems already in place. Therefore, the integration effort may be more difficult. An effort underway to help with the integration of current government systems is MODELS (Modernization of Defense Logistics Standard Systems). MODELS is designed to enhance functional capabilities, to improve logistics interfaces and data flows, and to ease EDI implementation. (22)

While these issues may make the implementation of EDI within government more difficult than the implementation within industry, these issues will not prevent the government's use of EDI. However, implementation strategies for the government's use of EDI, whether developed in-house by the

Continued on page 41

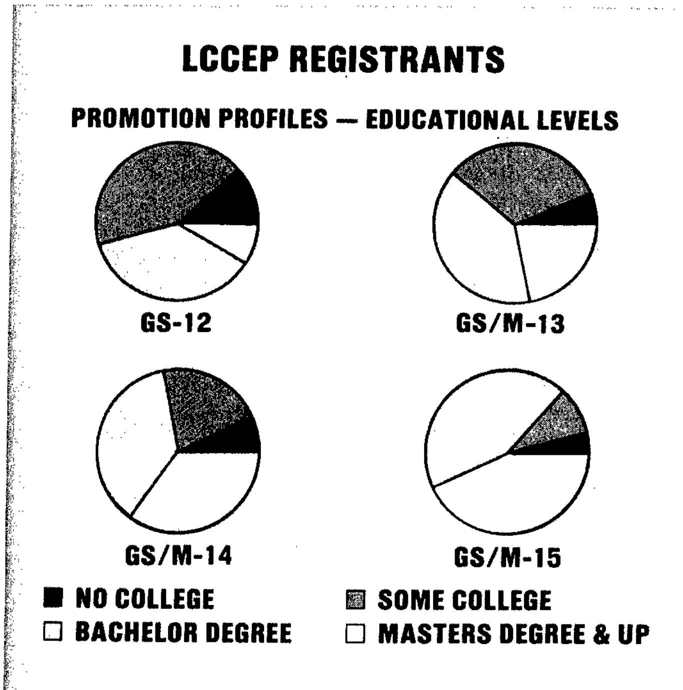
CAREER AND PERSONNEL INFORMATION

Civilian Career Management

A College Education

How important is a college education in the civilian work force today? After reading the facts, individuals can decide for themselves.

Of the Logistics Civilian Career Enhancement Program (LCCEP) registrants promoted during FY88 to grades GS/GM-12 through 15, 53% had college degrees, 37% had some college, and only 10% had no college. The chart below depicts educational levels of LCCEP registrants promoted to grades GS/GM-12 through 15:



Note that, as the grade level increases, the percentage of registrants with a college degree increases. At the GS-12 grade level, 44% of the promotees had a college degree; at the GS/M-13 grade level, 61% had a college degree; at the GS/M-14 grade level, 72% had a college degree; and at the GS/M-15 grade level, 87% had a college degree.

Not only do the numbers show that the percentage of individuals with a college degree increases as the grade level increases for promotion, but the GS/GM registrant population reflects the same type of trend. This is especially true in the 13 through 15 grade levels. The data below reflects the percentage of LCCEP registrants in grades 13 through 15 who have a college degree today as compared to data from FY83.

GRADE	FY83	FY88	DIFFERENCE
GS/M-13	61%	67%	+6%
GS/M-14	68%	76%	+8%
GS/M-15	59%	83%	+24%

Again, as the grade increases, the percentage of registrants with a college degree increases.

There are many opportunities available to individuals who want to obtain a college degree. LCCEP offers Undegraduate Level (Upper Division) Logistics Management Training at civilian institutions. Starting with the 1985/1986 academic year, 30 LCCEP registrants took advantage of this program. Limited spaces exist and competition is intense. The LCCEP Career Development Section solicits nomination packages from major commands and air logistics centers in January. A nomination package must be approved and submitted to the LCCEP (through senior logisticians at the major commands or air logistics centers) by March. In addition to the LCCEP Undergraduate Program, individuals can apply for reimbursement of certain costs incurred in taking college courses related to their jobs. They should contact their supervisor or local servicing Central Civilian Personnel Officer for requirements and procedures. Of course with continuing budget constraints, training monies are not always available. If this happens, they should check with their local college or university about tuition assistance programs and student loans. A college degree can pay for itself.

What if an individual already has a college degree? The LCCEP offers additional educational opportunities with industry, Graduate Level Training at the Air Force Institute of Technology and civilian institutions, and senior and mid-level Professional Military Education (PME) Management Development Programs.

If you would like more information on the rules and procedures associated with these programs, call the LCCEP Career Development Section at AUTOVON 487-5352/5351 or commercial number (512) 652-5352/5351.

(Linda Russell, AFCPMC/DPCMLD, Randolph AFB TX, AUTOVON 487-5631)

AFLC's Acquisition and Productivity Initiatives

New programs at AFLC in acquisition and contracting are breaking down barriers that have stifled innovation. AFLC is rapidly taking the Department of Defense lead in assuring quality in the areas of acquisition and has had great successes in taking advantage of America's system of free enterprise.

Forty-two percent of the command's contracting dollars were awarded through a competitive process. The competition in contracting programs has also expanded the number of potential suppliers for parts with some 5,500 new sources being developed last year. Another initiative is termed "Blue Ribbon Contracting." We contract with those vendors who provide quality goods and have proven they are quality vendors. "It permits us to award contractor bids which may not be the lowest bid, but those that represent the overall best value to the government."

Contractors' financial successes are being keyed on reliability and maintainabiility (R&M) concerns, such as how long parts or systems last without breaking or failing and how easy they are to service. Quality is the watchword across all Logistics Command activities.

General Alfred G. Hansen
AFLC Commander
Oct 1988

CALS Technology for the Soldier, Sailor, and Marine

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New technology promises to make Computer-Aided Acquisition and Logistic Support (CALS) a reality. The author predicts how this new technology will assist the technician and logistician in the near future.

Imagine the year is 1998. An Air Force avionics technician rolls a maintenance cart toward a Stealth aircraft. On the cart are tools, an umbilical for attaching to the aircraft, and a general-purpose, 32-bit microcomputer. Having attached the umbilical, the technician places a Compact Disk Read Only Memory (CD ROM) and Write Once, Read Mostly (WORM) into the micro. Initializing the micro activates a real time clock and an audit trail of the technician's procedures; these will be written to WORM. The technician initiates a series of performance tests, which are read from the CD ROM by the micro. Once a failure is discovered and verified, the technician proceeds with the repair process using the tech manual portion of the CD. Since the tech manual is interactive, the technician may read the procedure, respond to a test, or view a full motion video of the failed item's removal procedure, via the micro's state-of-the-art display. Having fully understood the failed item's removal procedures, the technician then removes the failed item, while fully observing appropriate safety precautions. If required, the technician installs the failed item into a test jig and reverifies the failure. Once fully satisfied that the item has failed, the technician calls up a complete parts list from the CD ROM, including the manufacturer's identification and stock number, as well as a template of a MIL-SPEC form for ordering the part. Using a light pen, the technician selects the appropriate information and signs the signature block on the display. A laser printer provides on-demand hardcopy. By selecting a menu, the technician may then initiate a parts procurement cycle. The micro, via internal modem, calls and passes all required logistic information. The entire operation is written to WORM. Successful completion of the parts procurement cycle occurs when the replacement item is delivered, installed, tested, and all analysis information is passed to the appropriate accounts.

The technician in this scenario could just as easily have been a soldier or marine in the field, or a sailor on board ship. This type of CALS technology is not only feasible, but is also being demonstrated on a limited basis. Using this technology for CALS will maximize efficient use of the technicians' talents, while minimizing their paperwork. Perhaps more importantly, the analysis will become even more comprehensive, accurate, and efficient.

Let's first address the issue of microcomputers. Microcomputers presently available for the office, such as the Compaq Deskpro 386 and the Apple Macintosh II, scream along at several times the speed of a VAX 11-785, a pretty formidable minicomputer.[1] Motorola's new 68030 microcomputer promises to be 40% faster than the 68020 in the Macintosh II.[2] According to a Motorola spokesman:

> Systems designed around the 68030 could be offered starting at $2,000 because they would not require extra components such as graphics coprocessors, memory management hardware and static random access memory chips.[3]

The first 68030 workstations are already becoming available, although at significantly more than $2,000. What may be available in five years?

> Imagine a system running an [INTEL] 80586 processor at 35 MHz and 20 MIPS with 64 megabytes of RAM, a 300-megabyte hard disk drive acting as a cache for 1 to 10 gigabytes of erasable optical storage, a 20-megabyte 3½-inch floppy disk drive, and 2,000 by 2,000 pixel screen resolution with built-in LCD shutter to produce 3-D images and thousands of on-screen colors.[4]

What about the Department of Defense's stringent requirement for computers that can run the Ada language? "Alsys with validated Ada compilers on the 80286 and 68000 computer architectures has announced the successful running of an Ada compiler on a Compaq Deskpro 386."[5] Certainly, it would appear that microcomputer hardware will not be a problem.

In order for our CALS scenario to work in a manner transparent to the technician, the micro's operating system must be multitasking:

> The utility of multitasking . . . is not to have one person run a dozen applications simultaneously, but to have many programs resident in memory at once. . . . In the future it will be an absolute essential, especially with business applications. I can edit a program . . ., save it to a RAMdisk, start up a terminal program, press a key to automatically dial my office, log-on to my office computer, upload the source code from the RAMdisk . . ., instruct the office computer to compile the program while saving any errors in the capture buffer, and then log off. Big deal, right? Except that . . ., I can return to the text editor while the entire procedure takes place. Neither application is slowed noticeably by the other.[6]

Multitasking operating systems have been around for years, but it is only recently that they have appeared in the personal computer market. One personal computer, the Commodore Amiga comes standard with a multitasking operating system, AmigaDOS. The advent of IBM OS2 and UNIX promises to bring multitasking to other major players in the microcomputer market.

The choice of display is even more flexible. In addition to the state-of-the-art display, we might choose an electroluminescent or some other type active element display, including a cathode ray tube (CRT). Apple is looking at active element displays for its proposed Macintosh laptop, and Truevision has developed a high resolution display card for the Macintosh II, which can display up to 2,048 by 2,048 pixels, from a palette of 16.7 million colors.[7]

Although there is a shortage of semiconductor RAM at present, this problem is temporary and presents no problem to our scenario. Several companies are already shipping 1-megabit DRAMs and:

> Fujitsu America has recently begun shipping 4-megabit chips in evaluation quantities to some developers and OEMs [Original Equipment Manufacturers]. . . . According to a Source at Fujitsu America, by 1992, it is expected that these memory chips will reach the price per bit which will make them preferred over the 1-megabit chips. That will facilitate possible motherboards with 4 megabytes of base memory and expansion cards with up to 32 megabytes on a single card.[8]

High density RAMs are only half the mass storage story. The other half includes very high capacity (over 400 megabytes) magnetic and optical disk technology. Both types are already becoming available, but even this does not tell the entire story, since optical disks come in three categories: CD ROM, WORM, and Erasable.

CD ROM technology is the most familiar, since it is ready analogous to musical compact disks, which have become a staple of the home entertainment industry. "The CD ROM disc, physically identical to an audio compact disc, can hold 550 megabytes of information, the equivalent of about 250,000 pages of text or the storage capacity of 1,600 floppy discs."[9] Like compact disks, CD ROMs must be professionally mastered; their contents are not easily erased. However, there are some distinct advantages to using this technology instead of alternate optical disk methodology. The government certainly does not want the technicians to alter the contents of their technical manuals or troubleshooting disks inadvertently. CD ROM players are also presently much cheaper (around $700) than WORM or erasable optical disks ($2,500-$12,000). This may change if Tandy delivers an erasable optical disk player for under $500 as they have announced. However, this cost reduction advantage still does not address the problem of inadvertent erasure. NSA Publishing of Bethesda, Maryland, is already offering, via CD ROM, Parts-Master, which:

> . . . allows you to locate and retrieve critical information on over 12 million parts and products procured and/or stocked by the U.S. government. . . . [Parts-Master accepts] (1) Barcode reading that automatically inputs NSNs or Part Numbers at "the wave of a wand" and (2) Reading NSNs, NIINs or Part Numbers from a floppy disk generated by your computer.[10]

Electronics Encyclopedia is also available on CD ROM.[11]

WORM drives will be invaluable as audit trail devices, since their high storage capacity and resistance to alteration (once written) will make comprehensive archiving simple and practical. Maxtor Corporation, in cooperation with Ricoh of Japan, has recently announced an 800-megabyte 5¼-inch WORM drive with embedded Small Computer System Interface (SCSI) and removable media.[12] Kodak has begun delivering a WORM information system that can store over a terrabyte (1,000,000 megabytes) of information![13]

Artificial intelligence, in the form of expert systems, completes our technology requirements:

> Imagine capturing the expert knowledge and reasoning power of Albert Einstein in a PC. Generations succeeding him could gain his wisdom and reap the benefits of his intuitive power by accessing the information whenever desired. . . . Artificial intelligence tries to free the flow of information through expert systems. Expert systems capture the valuable knowledge and experience of today's technical, financial, and medical experts, preserve it, and make it readily accessible to less experienced end users.[14]

Let us now complete our original scenario. The failed item has arrived at depot repair. The depot technician places the failed item into the test jig and loads test software into the tester computer. The tester computer identifies the failed component or components. Test results are written to WORM and sent via modem to a supermicro, a micro running at speeds many times that of today's mainframes. An expert system running on the supermicro analyzes the test results and determines the following: how many replacement components to order from the manufacturers; what the actual mean time between failures (MTBFs) for those components are; whether the actual cause of the failure is defective components or a design problem; and, if the problem is one of design, what may be done to correct the fault. The expert system could, in the more distant future, even write the proposed engineering change notice, if desired.

Some experts have expressed doubts about the necessity, or even the desirability, of CALS:

> The design and implementation of CALS, however, face a number of formidable hurdles. Defense contractors, for instance, are skeptical because they wonder what CALS will ultimately cost them. Moreover, Pentagon and service offices are in a quandary as they ponder how and where to begin. To be successful, CALS planners must limit their objectives. For instance, there is no operational reason why all logistics activities should be digitized. In addition, the more ambitious CALS becomes, the more technical problems it will encounter. Everyone involved with CALS realizes that it has great potential. But it will fulfill that potential only if more people are aware of its limits.[15]

Let us remember that most of the doubts about CALS have revolved around cost. Ten years ago, digital watches cost about $70. Today, they are prizes in bubblegum machines. The question is *not* whether we can afford CALS. The question is whether we can afford *not* to have CALS.

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Notes

1 "Compaq releases the first of the 386s," *Computer Shopper*, November 1986, p. 71.

2 The, Lee. "32-bit Showdown: Macintosh II versus Compaq Deskpro 386," *Business Software*, April 1987, p. 29.

3 Alper, Alan. "Motorola loads up 68030," *Computerworld*, 2 November 1987, p. 10.

4 Brownstein, Mark. "Future Technology: To Boldly Go Where No PC Has Gone Before ...," *InfoWorld*, 8 February 1988, p. 21.

5 "Alsys Ada Compiler for Compaq Deskpro 386," *Computer Shopper*, February 1987, p. 157.

6 Jennings, Kenneth. "Amiga vs Atari: Will the 'True' Atari Please Stand UP?" *Computer Shopper*, April 1987, p. 128.

7 Doherty, Richard. "Computers: Card gives MAC II hi-res," *Electronic Engineering News*, 29 February 1988, p. 76.

8 Brownstein, Mark. "Future Technology: To Boldly Go Where No PC Has Gone Before ...," *InfoWorld*, 8 February 1988, p. 22.

9 LaPlante, Alice. "Big Eight Accounting Firm Finds CD ROM Eases On-Site Auditing," *InfoWorld*, 8 February 1988, p. 24.

10 NSA Publishing advertisement, "The Dawn of a Total Electronic Logistics Support System on Compact Disk Has Gotten Brighter. Now with IL's (Technical Characteristics)," *Military Logistics Forum*, May 1987, p. 49.

11 KnowledgeSet advertisement, "Go from Need to knowledge in seconds with KnowledgeSet CD-ROM Rapid Access Software...," *Information Center*, March 1988, p. 13.

12 "800-Megabyte Optical Disk Drive," *Computer Shopper*, February 1987, p. 260.

13 Kodak advertisement mailer.

14 Brown, Lauren. "Expert-System Shells are in No Way Omniscient: Plan Ahead," *PC Week*, 9 February 1988, p. 59.

15 Elwood, Robert W. "CALS: Promise and Problems," *Military Logistics Forum*, May 1987, pp. 44-45.

▶ *Continued from page 12*

23. US Air Force Systems Command. *Modification Management*. AFSC Pamphlet 57-2, Washington DC: Government Printing Office, 1982 (rescinded pub).
24. US Air Force Systems Command. "Minuteman Long Range Plan (MLRP) Program Management Plan." Plan created by the Ballistic Missile Office, Norton AFB CA, 16 December 1985.
25. Zorich, Lt Col David, USAF. "Class V Mod Improvement Plan." Briefing charts plus personal interviews. Presented to the Air Force Council, Pentagon, Washington DC, 22 May 84. Personal interviews conducted May through July 1984.

(This article will be continued in the Spring issue.)

Analysis of D039 Interfaces

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Introduction

A high percentage of a new weapon system's components are usually identical to existing components in the inventory or components which can be slightly modified to serve the same purpose. For example, 80% of the components of the F-15, F-16, and A-10 can be used or modified for repairing other aircraft. This means the Air Force can rely upon field experience to determine the proper quantity of these components for Tables of Allowance (TA). In determining the proper allowance for such tables for the remaining 20% of a new aircraft's components, the Air Force must rely heavily upon estimates of failure rates and average repair times of the craft.

This report centers on techniques involved in answering the complex questions of equipment, spares, meantime between failures (MTBF), and service time trade-off. Actual data were used to validate the model and confirm its logic and potential value.

Background

The Air Force Logistics Command (AFLC) is responsible to field and support aircraft weapon systems and related support equipment used by operating commands to perform missions. The budget requirements for this equipment are currently forecasted by the Equipment Item Requirements Computation (D039) system. This system is used to predict new and replacement equipment requirements up to seven years in advance of operational needs in order to sustain a specific weapon system's required level of peacetime and wartime mission capability. The system's forecasting problem is compounded by the diversity of equipment types and the effects of time (age, wear, condemnation and replacement, or obsolescence and replacement). These factors keep a typical base's equipment requirements in continual flux.

The essential elements for forecasting replacement and repair requirements are contained within the AFLC procedures for computation of equipment requirements. AFLCR 57-2, *Computation of Requirements for Equipment Type Items,* reduces the requirements to the following simplified formula:

> Equipment authorizations applied to projected organization programs, plus additives and replacement requirements, minus total assets (including unordered and funded), equal net shortage or excess.

The requirements are altered to comply with inventory analysis reporting, buy/budget, and program objective memorandum purposes.

This study was conducted to develop cost-effective models that predict new and replacement equipment requirements in order to achieve weapon system availability and support goals. The study included the following activities:

(1) Analysis of current D039 and interface systems.
(2) Statistical analysis of equipment demand/service time data.
(3) Development of equipment requirement classification systems.
(4) Development of equipment requirements forecast models.
(5) Validation of forecast models.

D039 Interfaces

The principal goal of the D039 is to compute the net buy/budget for all USAF equipment requirements. D039 ultimately depends on three primary data sources: OFAEDs (Organization Forecast Authorized Equipment Data) and DFAEDs (Data Forecast Authorized Equipment Data), and net authorized support equipment deviations from the TA for all Air Force bases.

A detailed description of the procedures for the determination of the initial support equipment TA is presented in AFM 800-5, *Unit Cost Reports (UCR)—RCS: DD-COMP(Q&AR)1591 and Selected Acquisition Reports (SAR)—RCS: DD-COMP(Q&A)823.* Figure 1 depicts the basic procedures in the TA initialization subsystem; the system flowchart is self-explanatory. The activities in this subsystem have ordinarily been completed 12 to 18 months prior to the delivery of the new weapon system to the first organizational units. These units will typically be authorized the full complement of support equipment allowed by the TA. As field experience is achieved in the new weapon system, authorizations may decrease and changes may be made to the TA. At this point, the TA modification subsystem will be used to incorporate these changes to the TA while maintaining control over support equipment requirements. Figure 2 depicts the basic procedures in the TA modification subsystem. Together with the flowchart depicted in Figure 1, these two subsystems appear to be the best candidates for modification to include an allowance evaluation process.

The input from OFAED and DFAED to D039 relates only to the future support equipment requirements (from six months to six years in the future). On-hand or on-order support equipment is tracked primarily through the standard base supply system (SBSS or D002A) from which TA variations are reported to C008. The C008 maintains the primary records of all equipment in Air Force inventory.

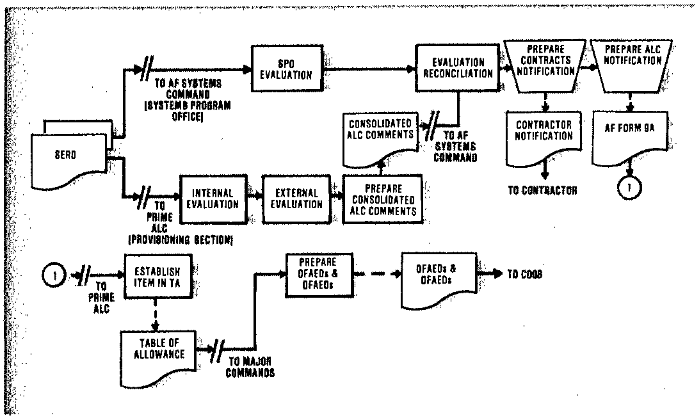

Figure 1: TA Initialization Subsystem.

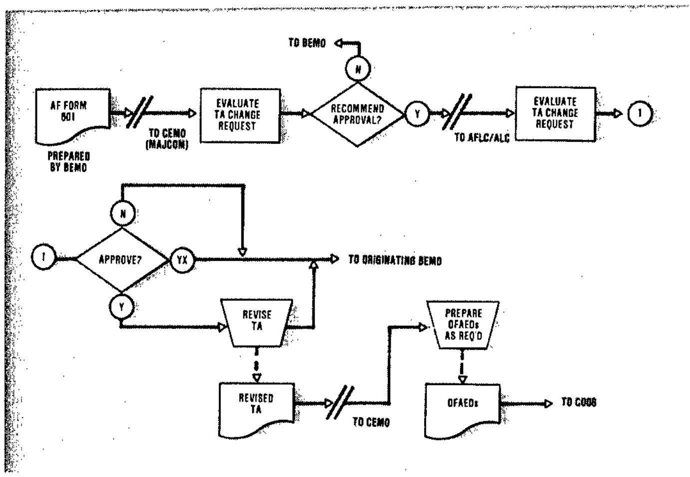

Figure 2: TA Modification Subsystem.

As the final information system in the support equipment budgeting process, the D039 obviously processes huge quantities of data and is therefore run infrequently (two primary runs per year). This infrequency and the sheer volume of data may discourage its user to consider alternatives.

Literature Review

The Air Force commonly uses the variance-to-mean (V/M) ratio to work recoverable item computations. Sherbrooke (21) has proposed that these prediction techniques can be improved by two methods: a more appropriate model and development of an estimation model. Exponential smoothing is a suggested method which allows for items with non-contrast means; it has proved to be consistent for V/M prediction. The recommended formula is:

$$V/M = 1 + AMB$$

where:

$A = .141 + .0125Q$
$B = .583 - .0045Q$
$M = \text{Mean}$
$Q = \text{Number of quarters.}$

The research of Stevens and Hill (22), who have also worked on prediction of the V/M ratio, has determined that using the standard value of 1.01 for V/M can give misleading conclusions. Their suggested method for improving the V/M prediction technique is based on recoverable items in the ALS marginal analysis algorithm. This method proposes a better means for predicting this important ratio, using the formula V/M = AB, where A and B are regression coefficients.

Carrillo and Hillestad (3) in a study on nonstationary behavior found that:

> Two problems regarding recoverable item inventory faced by a decision maker for the nonstationary case are the same as those faced in the steady-state case, that is, to determine how much spare stock to provide against stockouts and to determine what level of performance can be achieved with a given level of investment in spare stock.

Cannibalization of certain items is also discussed and models are provided in their report.

Replacements for most items "are computed in the D039 system by developing a replacement factor based on the last two years of condemnation and quantity in use. This factor is multiplied by the projected population and by a time factor to determine the replacement requirement." Another method infrequently used develops factors which are based on an item's age, life expectancy, and the probability of its condemnation. Upon conducting a study with Phillips Petroleum Company concerning vehicle replacement, Waddell (23) found that a dynamic programming algorithm can be used to determine a new replacement policy that "will maximize discounted cash flow." A study by Brown, Mahoney, and Sivazlian (2) determined that the service age of a piece of equipment which has been repaired due to breakdown should be adjusted in accordance with the breakdown. Gottilieb (8) considers a replacement policy in which failure rate is not necessarily increasing and replacement can occur at any time. From this study, he formulated an optimal replacement technique. In a study which involved a replacement system which considers deterioration over time, Iyer and Sivazlian (11) have derived a formula which will calculate the expected cost for each time period. Murphy and Nguyen (17) discuss replacement policies considering imperfect repair, "in which the mean life of a repaired system is less than the life of a new system," and develop optimal policies which will minimize cost per unit of time. Berg (1) defines the marginal cost of a replacement and is able to calculate it in terms of a certain parameter. The calculation can then be used to obtain an optimality equation for two objective functions: "(1) The expected cost per unit time, and (2) the expected total discounted costs."

DiVeroli (6) investigated equipment subject to failures which had randomly distributed repair costs and developed an algorithm which calculated the optimal policy. Kowada and Nakagawa (14) suggest a definition in which failure rate is the base; from this definition, probability distributions for failures can be calculated.

For those problems concerning multiple repair (each repair done by a special crew), Gaver and Lehoczky (7) have developed a stochastic model which predicts a normal, steady-state distribution.

For those problems concerning bulk service, Chaudhry and Easton (5) have formulated a potentially useful model which states that "interarrival times are assumed to follow an Erlangian distribution. Steady-state results . . . are arrived at in terms of the unique root of the characteristic equation." Chakravarthy and Neuts (4) studied a single server queue model with independent and "identically distributed service times, having a common distribution of phase type." Key points are mathematical descriptions of the arrival process, algorithms to compute stationary distributions relevant to the queueing model, and an interpretation of numerical examples.

"It is demonstrated that this queue has an embedded Markov Chain of a particular block-partitioned kind, whose invariant probability vector in the stable case is of matrix-geometric form." Monahan (16) used the Theory of Partially Observable Markov Decision Process and formulated a model "which combines the classical stopping problem with sequential sampling at each stage of the decision process."

Niv (18) analyzed a queueing loss model involving "a heterogeneous arrival and single-service queueing loss model . . . in which the arrival process of customers is assumed to be a nonstationary Poisson Process with an intensity function the evolution of which is governed by a 2-state continuous time Markov Chain." It allows service distribution to change for each different customer. In some cases, it seems that the more regular the arrival process, the lower the loss. Halachmi (9) discusses a solution to the G/M/K queueing system that is based on the Fokker-Planck equation for the diffusion processes.

Robinson (20) discusses the problem of how to optimally control "a semi-markov chain with countable state space and unbounded costs." This policy specifies a higher priority rating for one of the queues. The priority depends on the time distribution of the other queue and the length of the higher priority queue. Lavenberg (15) derives an expression for the "Laplace-Stieltjes transform of the steady-state distribution of the queueing time for the M/G/1 finite capacity queue." It was found that "the mean queueing time increases and the coefficient of variation of the queueing time decreases as the mean service time increases."

Poisson Assumption

A great deal of the literature reviewed seems to indicate that many resource planning models assume exponentially distributed demand times and mean service times. An alternative to this M/M/1 queue analysis was proposed by C. C. Sherbrooke. (21)

In an earlier report (10), outliers were discarded through the use of an arbitrary cutoff point. Sherbrooke improved this technique by using a statistical test of means to identify outliers; however, further improvement is still needed. The mechanisms causing aberrant demand rates should be determined through careful field studies performed by the investigators who analyze the data. Thus, the reasons for discarding data could be precisely documented in each case and used to clarify the process being modeled. The remaining data would then more closely represent a precisely defined, homogeneous population.

In addition to contributing to the homogeneity of the population to be analyzed, identification of process mechanisms during field work would contribute to the generalized nature of the solution. In contrast to empirical fitting of data, an explanation of processes gives strong support to the application of the mathematical model developed to other, similar situations.

With regard to the F-16 data, Sherbrooke cites a change in means over time for some parts. One factor to consider is that data were collected on new F-16s over a relatively short span in their useful lives. The F-16s may still have been in their break-in period rather than in steady-state, in which they should have been modeled.

How strong is the evidence against a Poisson distribution? Sherbrooke used the Poisson index of dispersion to investigate the stability of means over time. The number of items Sherbrooke claims are non-Poisson (about 17/150) represents a small portion of the entire population even before that number is possibly reduced by explaining why such items have unusual behavior and discarding those which do not fit the population being modeled.

If further investigation reveals that the process being modeled is not Poisson, then which model should be used? The exponential smoothing method proposed by Sherbrooke requires all V/M $\geq$ 1.0. In Sherbrooke's Table 4.2, 67/159 had a V/M $\leq$ 1.0. This argues against the use of the exponential smoothing model. In fact, 77/159 have a V/M between .5 and 2. The Poisson assumption requires Variance = Mean, and therefore V/M = 1.0. It is worth noting that about half of the V/Ms in question are quite close to the value of Poisson populations. Some alternate methods of modeling time-variant means are: (1) M/G/1 queue with embedding techniques (13), (2) use of the Markov Property, and (3) use of Khintchine's theorem. (12) Until the traditional assumptions of Markovian processes are disproven by collection of more recent data and by field analysis of process mechanisms, the models currently being developed will assume M/M/1 conditions.

Procedures

The objective of each developed model was to determine the optimal numbers of equipment and spares to be provided at a given location in order to minimize the expected costs and maximize the expected number of operational aircraft.

A closed loop, series queueing model was used for modeling the first seven situations to be discussed. Model 1 is a situation involving peacetime conditions describing the interaction of and expected effects upon costs and availability of aircraft within the system during usual operating conditions. For simplification, a problem situation was considered in which there are only two aircraft, no spares, and one piece of equipment in the system. Assumed data for this problem are given in Table 1. Only three states for the number of down aircraft exist here: zero, one, or two.

DATA FOR EXAMPLE PROBLEM
(Two Aircraft)

Assumed Data

Test Equipment Cost	$ 20,000 Annualized
Spare Cost	$100,000 Annualized
Aircraft Down Cost	$ 3,000 per day if one aircraft down
	$ 8,000 per day if both aircraft down
Mean Time Between Failures	10 Days or 15 Hours MTBF
Repair Time	1 Day or 24 Hours

Table 1.

To solve for the steady-state probabilities, Π, of being in each state at any given time, the following formula must be solved:

$$\Lambda\Pi = 0 \text{ where } \sum_{i=1}^{n} \Pi_i = 1$$

and n is the matrix of transition probabilities for going from one state to another. The expected total cost equation for this formula is:

$$\text{Total Cost (annualized)} = \text{Cost of Spares} + \text{Cost of Equipment} + \text{Cost of Aircraft Down Time.}$$

For the example:

$$\begin{bmatrix} -.2 & .2 & 0 \\ 1 & -1.1 & .1 \\ 0 & 1 & -1 \end{bmatrix}$$

therefore,

$$\left[\, \Pi_0\ \Pi_1\ \Pi_2 \,\right] \begin{bmatrix} -.2 & .2 & 0 \\ 1 & -1.1 & .1 \\ 0 & 1 & -1 \end{bmatrix} = 0$$

with $\Pi_0 + \Pi_1 + \Pi_2 = 1$.
Solving for Π, gives = [.820, .164, .016].

Therefore, the steady-state probability that zero aircraft are down (Π_0) is 0.820, that one aircraft is down (Π_1) is 0.164, and that both aircraft are down (Π_2) is 0.016. Substituting these values and those in Table 1 into the previous total cost equation provides the total cost associated with the system:

$$\text{Total Cost} = 0 + 1\,(20{,}000) + 365\,[(3000\,(.164) + 8000\,(.016)\,] = \$246{,}300.$$

Model II assumes wartime steady-state conditions; this situation was modeled by increasing sorties from one to three per day, and by adjusting the appropriate failures per day accordingly. The same formulas and programs were used as for Model I.

Model III is the transition from peace to conflict. The purpose of the model was to observe the effects upon expected costs and availability of aircraft, when a transition from steady-state peacetime conditions to steady-state wartime conditions occurs.

The following formulas from Phillips, et al. (19) and Kleinrock (13) are used to solve the transition probabilities from state i to j:

$$\frac{dP(t)}{dt} = P(t)\Lambda$$

where,

$\frac{dP(t)}{dt}$ is the matrix whose (i, j)th element is $\frac{dP_{ij}(t)}{dt}$,

P(t) is the matrix whose (i, j)th element is $P_{ij}(t)$, and

$P_{ij}(t)$ is the probability of changing from state i to state j, and

Λ is the transition rate matrix.

One of the state equations generated is replaced by:

$$\sum_j P_{ij}\ (t) = 1.$$

The set of equations were then solved by using the Runga-Kutta approximation technique.

Depot maintenance situations, Model IV, were modeled from an expanded version of Model I, adjusting the appropriate repair rate accordingly. Two variations were modeled: (1) all repairs were done at the depot, and (2) a random 50% of the failures were sent to the depot for repair and the remaining 50% to the base.

Model V, involving breakdown of maintenance equipment, was modeled by providing a random process in Model I which simulated and determined when a breakdown occurs. Once breakdown occurred, the appropriate values were adjusted accordingly until the repair time for the piece of equipment had expired; it would then be readjusted to account for the fact that the maintenance equipment could itself be reused for repair.

Model VI, condemnation, was modeled by providing a random process in Model I to simulate when an item was to be condemned. Once an item was condemned, the system degraded (decreased the number of items in the system) until a new item was introduced into the system. No additional cost was added to the calculation for spare parts since it was assumed that these new items were not a cost of the part in the total supply system under study.

Model VII, determining the optimal number of equipment and spares to achieve desired aircraft availability, requires that an additional constraint be added to Model I before it can be modeled. This constraint forced the probabilities associated with the number of operational aircraft to be greater than or equal to the desired availability with any assigned probability.

Each version of Models I - VII was solved in a manner similar to that outlined for Model I. The transition probabilities change depending upon the number of aircraft, spares, and pieces of equipment in the system. Expected costs and resultant state probabilities also vary with the system.

Total Aircraft Analysis

Following the focus on a system's individual components, the study next turned to a focus on the entire aircraft. Given that an aircraft is made up of n components, each assumed to have a Poisson process for failures and each component to be independent of the others, Λ, the failure rate of the aircraft, is equal to $\Lambda_1 + \Lambda_2 + \ldots + \Lambda_n$, the sum of the failure rates for the individual components. The probability that the aircraft will be operational at any given time is equal to:

$$1\text{-P(at least one component failed)} = [1\text{-}(P_1 + P_2 + \ldots + P_i + \ldots + P_n)] = P_0$$

where:

P_i = exactly i components failed
and P_0 = all n components do not fail.

If it can be assumed that the failure rate of the aircraft is equal to one minus the probability that the aircraft is operational at any given time, then:

$$\begin{aligned}\text{P(aircraft is operational)} &= 1 - \Lambda \\ &= 1 - [\Lambda_1 + \Lambda_2 \ldots + \Lambda_n].\end{aligned}$$

If the failure rates for the individual items are not known, then:

$$\begin{aligned}\text{P(aircraft is operational)} = {} & \text{P(component 1 is operational)} \\ & \bullet\ \text{P(component 2 is operational)} \\ & \vdots \\ & \bullet\ \text{P(component n is operational).}\end{aligned}$$

If the failure rates for all items can be assumed to be equal, then this simplifies to:

$$\text{P (aircraft is operational)} = \text{P [one component is operational]}^n.$$

Estimating Aircraft Availability

A procedure has been developed which links failure and repair rates of components to the overall availability of the aircraft. Given two of the three variables in the following expression, the third may be estimated, or if given the value of one, a family of curves may be generated, and the values of two unknowns determined by some criteria such as minimal cost.

$$1/F = \Lambda = \frac{1 - Av}{(M)\cdot(Av)}$$

where Av is the availability of the component, M is the mean time to repair a component (in hours), and F is the mean time between failures for a component (in hours).

F may be estimated by assuming that all components with a short MTBF and with several independent ways of failing have a Poisson distribution. Those components with large MTBFs will be treated as one large component.

The next step in the process is to estimate the average time required to make a repair for each of the resultant components. For example, the average repair time for a component may be estimated by using the average of components of the same or of a similar nature on other aircraft. Hence the average would be:

$$\overline{M}_i = \frac{\sum_{j=1}^{N_i} f_j M_j}{\sum_{j=1}^{N_i} f_j}$$

where $\overline{M}_i$ is the mean repair time for component i (in hours), N_i is the number of independent items in component i which can fail, f_j is the frequency of failure of items j, and M_j is the average time to repair item j (in hours).

If there is no history on a component, then $\overline{M}_i$ must be estimated by the manufacturer or other experienced person. Another method to obtain this value is:

$$\overline{M}_i = \frac{\sum M_j}{N_i}$$

However, if the mean is unknown but the MTBFs for components and desired availability are known, then $\overline{M} = \frac{F\,(1 - Av)}{Av}$ gives the desired overall average. As an approximation,

$$\overline{M} = \frac{\sum_{i=1}^{C} \overline{M}_i}{C}$$

where C is the number of components. Then,

$$\overline{M}_d = \overline{M}C - \sum_{\substack{i=1 \\ i \neq d}}^{C} \overline{M}_i$$

If $\overline{M}_i$ are not known, then $\overline{M}_d = \overline{M}$ may be used as an estimate.

The least cost combination of equipment and spares which yields a mean time to repair less than or equal to $\overline{M}_d$ should be selected.

Another option is to redesign the component to give a higher MTBF. Cost tradeoffs may be developed to yield the best tradeoff among components, equipment, and spares. Candidates for such studies are those which have high equipment and spare cost to achieve the given availability.

The component availability given the overall availability may be calculated as follows:

$$Av = \frac{F}{M + F}$$

then,

$$Av_d = \frac{F_d}{M_d + F_d}, \quad F_d = \frac{1}{\Lambda_d}, \quad M_d = \frac{1}{m_d}$$

$$\Lambda_d = \Lambda - \sum_{\substack{i=1 \\ i \neq d}}^{C} \Lambda_i \qquad m_d = M_\epsilon - \sum_{\substack{i=1 \\ i \neq d}}^{C} M_i$$

If no historical data are available, then $\Lambda_d = \frac{\Lambda}{C}$ and $m_d = M$. If an item of equipment is used for more than one component, it should be prorated on the basis of hours spent repairing each component, with this reflected in the value selected for its repair time.

Results

This study developed methodology relating to analyses of equipment and spares on new aircraft. For new aircraft with a limited data history, guidelines may be established to determine the amount of equipment and spares required. The best rule is to provide one set of equipment per wing. The allowance process is dynamic, and therefore this initial allocation in the Table of Allowances may be changed as failure and repair data become available.

As discussed earlier, the Poisson Assumption is adequate unless strong evidence suggests the contrary. This is true because a randomly failing part tends to fail in a Poisson manner regardless of the failure distribution of the components. Also, consistency of the failure and repair processes is assumed. The Markov property assumes that a maintenance action restores the part to its original state.

Conclusions

The selection of expensive equipment for new systems can be accomplished best by straightforward steady state Markov chains assuming a Poisson process.

In almost all cases, a base or an operating location can be serviced by a single item of equipment, rarely more than two, along with adequate depot support. Particular attention should be given to engineering for high reliability and short maintenance times to reduce peacetime costs and to ensure wartime readiness.

This study began with a desire to improve the Air Force's equipment forecasting and budgeting system. It became obvious that the D039 system acted as an accounting model by accepting equipment authorizations, quantities on hand, and force data from other systems to produce its forecast. The key to the forecasting process was pinpointed as the Equipment TA

which limits the type and quantity of equipment which may be authorized to an organization. Experts on the equipment allowance-authorization process agreed that aircraft maintenance organizations tend to request authorizations equal to their allowance; estimates ranged from 97% to 99%. This seems very plausible when one recognizes the uncertainty of wartime demands for equipment services. These findings caused the study to be focused on ways to improve the initial process of deciding what quantity of equipment should be allowed in a TA.

The actual process of establishing allowance quantities depends almost totally upon the following factors: failure rate, repair time, spares cost, equipment cost, and mission criticality. Field experience plays a dominant role in determining allowances when such experience is available. It has been suggested that some 80% of the components of current line aircraft are items off-the-shelf or items off-the-shelf with only slight modification. This permits experienced personnel to negotiate allowances with confidence on the majority of equipment items.

The remaining 20% of a new aircraft's components and support equipment are characterized by uncertainty. In particular, failure rate and repair time estimates often deviate as much as ten times the ultimate field failure and repair factors. The models developed in this study are immediately useful in setting equipment allowances for these items. Cost data are usually known and engineering estimates of failure and repair rates are available. The models accept these data and provide an excellent starting point for negotiating equipment allowances. Equally important, these models run very fast on a computer, which permits an equipment manager to answer contingency questions. Nothing can replace the insight of experienced equipment managers during allowance negotiations. However, when experience is limited, the model developed in this study can provide practical and needed information.

References

1. Berg, M. "A Marginal Cost for Analysis for Preventative Replacement Policies," *European Journal of Operational Research*, Vol. 4, No. 2, 1980, pp. 136-142.
2. Brown, J. R., Mahoney, J. R., and Sivazlian, B. D. "Hysteresis Repair in Discounted Replacement Problem," *IEE Transactions*, Vol. 15, No. 2, 1983, pp. 156-165.
3. Carrillo, M. J. and Hillestad, R. J. "A RANDNOTE," 1980.
4. Chakravarthy, S., and Neuts, M. F. "A Single Server Queue with Platooned Arrivals and Phase Type Services," *European Journal of Operational Research*, Vol. 8, No. 4, 1981, pp. 379-389.
5. Chaudhry, Y. M. L., and Easton, G. D. "The Queueing System EK/MA, B/1 and Its Numerical Analysis," *Computers and Operations Research*, Vol. 9, No. 3, 1982, pp. 197-205.
6. DiVeroli, J. C. "Optimal Continuous Policies for Repair and Replacement," *Operational Research Quarterly*, Vol. 26, No. 1, 1974, pp. 89-98.
7. Gaver, D. P., and Lehoczky, J. P. "A Diffusion Approximation Solution for a Repairman Problem with Two Types of Failure," *Management Science*, Vol. 24, No. 1, 1977, pp. 71-81.
8. Gottilieb, G. "Optimal Replacement for Shock Models with General Failure Rate," *Operations Research*, Vol. 30, No. 1, pp. 82-92.
9. Halachmi, B. "The Fokker-Planck Equation as an Approximating Formula for the G/MIK Queueing System," *Computer & Operations Research*, Vol. 5, No. 3, 1978, pp. 179-186.
10. Hill, J. M., and Stevens, R. J. "Estimating the Variance-to-Mean Ratio for Recoverable Items in the ALS Marginal Analysis Algorithm," Wright-Patterson AFB, Ohio, 1973, pp. 1-49.
11. Iyer, S. N., and Sivazlian, B. D. "A Dyadic Age-Replacement Policy for a Periodically Inspected Equipment Item Subject to Random Deterioration," *European Journal of Operational Research*, Vol. 6, No. 3, 1981, pp. 315-320.
12. Khintchine, A. Y. *Mathematical Models in the Theory of Queueing*, Hofner, New York, 1960.
13. Kleinrock, L. *Queueing Systems, Volume I: Theory*, John Wiley & Sons, Inc., New York, 1957.
14. Kowada, M., and Nakagawa, T. "Analysis of a System with Minimal Repair and Its Application to a Replacement Policy," *European Journal of Operational Research*, Vol. 12, No. 2, 1983, pp. 176-182.
15. Lavenberg, S. S. "The Steady-State Queueing Time Distribution for the M/G/1 Finite Capacity Queue," *Management Science*, Vol. 21, No. 5, 1975, pp. 501-506.
16. Monahan, G. E. "Optimal Stopping in a Partially Observable Markov Process with Costly Information," *Operations Research*. Vol. 25, No. 6, 1980, pp. 1319-1334.
17. Murphy, D. N. P., and Nguyen, D. G. "Replacement Policies with Used Items Constraint," *Journal of Operational Research Society*, Vol. 34, No. 7, 1983, pp. 633-638.
18. Niv, S. C. "A Single Server Queueing Loss Model with Heterogeneous Arrival and Service," *Operations Research*, Vol. 28, No. 3, Part 1, 1980, pp. 584-593.
19. Phillips, D. T., Ravindran, A., and Solberg, J. J. *Operations Research*, John Wiley & Sons, New York, 1976.
20. Robinson, D. "Optimization of Priority Queues - A Semi-Markov Decision Chain Approach," *Management Science*, Vol. 24, No. 5, 1978, pp. 545-553.
21. Sherbrooke, C. C. *Estimation of the Variance-to-Mean Ratio for AFLC Recoverable Items*, Final Report, January, Sherbrooke & Associates, Potomac, MD, 1984.
22. Stevens, R. J., and Hill, J. M. *Estimating the Variance-to-Mean Ratio for Recoverable Items in the ALS Marginal Analysis Algorithms*, Working Paper Number 49, Air Force Logistics Command, Wright-Patterson AFB, Ohio, 1973.
23. Waddell, R. "A Model for Equipment Replacement Decisions & Policies," *Interfaces*, Vol. 13, No. 4, 1983, pp. 1-7.

READER EXCHANGE

Dear Editor

I just wanted to pass on my thanks to you for including the article, "Some Thoughts on Combat Support Doctrine," in the Fall issue of the *Air Force Journal of Logistics.* I'm not sure I agree with everything in the article, but that isn't important. I'm convinced that very few people have read our doctrine and with what we think we know about doctrine, there is little agreement. It sounds like a subject we as a group should discuss further. I personally like what the Civil Engineers, headed by General Ellis, are doing—having students put doctrine together and rethinking what doctrine ought to be. But the real point, I think, is your/our *Journal of Logistics* must be an avenue to discuss logistics—and certainly any discussion may include disagreements.

You know, we want/demand a lot from our young people—they are the ones we expect to maintain this fine Air Force in the future. If they can't suggest some improvements to the system through means like the *Journal of Logistics,* then we are in serious trouble.

Please continue and encourage people to view their concerns, irritants, and suggestions for improvements to our fine magazine.

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Dear Editor

In the Fall 1988 issue of the *Air Force Journal of Logistics,* in an otherwise very fine article, Lieutenant Colonel Ronald A. Torgerson made one comment which I must address. The extract from the sentence which bothered me is "... our CE leadership, both officers and noncommissioned officers (NCOs) . . . ." What bothers me is the implication that there is a difference in kind between commissioned officers and noncommissioned officers, as opposed to one of degree. The extract should be worded "both commissioned and noncommissioned officers." As a Transportation Squadron Commander, I held my Sergeants to the same standards of officership as my Lieutenants and Captains—each was expected to act and perform as a professional officer.

I may be a minority voice crying in the wilderness, but I would like to put the word "officer" back in NCO. When I attended a graduation ceremony from the NCO Leadership school or NCO Academy, I would make it a point to talk to the speaker, usually a Wing or Numbered Air Force Senior Enlisted Advisor, and recommend he (I never had the occasion to meet a female SEA or I would have said he/she) speak at some future ceremony on just that subject. I had a Senior Master Sergeant read the paragraph from which the phrase was extracted to see if he would react to the same phrase. He did not. Perhaps I am overly sensitive to a non-issue.

In the article, "Wanted: Articles by Enlisted Personnel (Why We Don't Write)," Master Sergeant Lee McCray issues a call to the enlisted force to "act quickly to change these negative perceptions" concerning the literacy of the enlisted force. We must also act quickly to get the most out of our Air Force leadership. To that end, let's put the word "Officer" back in NCO and start the same discussions about officership in the NCO corps that the commissioned officer corps went through a few years ago.

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CURRENT RESEARCH

Air Force Logistics Command (AFLC) Logistics Management Sciences Study Program

The AFLC Directorate of Management Sciences (AFLC/XPS) is responsible for developing, managing, and executing the Air Force Logistics Command's management sciences study program. The Directorate is composed of three Divisions: the Assessment Applications Division (XPSA), the Concept Development Division (XPSC), and the Consultant Services Division (XPSM). We conduct and sponsor studies and research of significant logistics issues. We also use, modify, and develop new or improved methods, models, and tools to manage logistics resources. Our goal is to quantify the relationships between alternative logistics resources and resultant aircraft availability so AFLC can prioritize and justify its investments in those resources. We work toward this goal by performing/sponsoring studies for customers in the headquarters and by pursuing a few internally developed projects which have significant potential for providing valuable insights into these relationships. We will work closely with our customers as we design and perform our studies to ensure we have a healthy balance between the rigorous application of operations research techniques and practical, "implementable" solutions.

The following projects are representative of the work we will be involved in during FY89. We also plan to take on some shorter term projects.

Distribution and Repair in Variable Environment (DRIVE): DRIVE will prioritize depot repair and retail distribution actions to best achieve the availability goals of operational commanders. It will do this by assessing the need of the field given availability targets and current asset position by base (serviceable, awaiting parts (AWP), in-transit) and determining the most effective mix of actions within cost constraints. Currently initial implementation is scheduled for FY91 with full-up implementation by FY94.

Weapon System Management Information System (WSMIS): We have supported WSMIS in a variety of ways over the past years. One subsystem that we will work on in FY89 is the requirements execution/availability logistics module (REALM). Areas that will be included are WRSK/BLSS requirements, budget execution, and engine requirements. We have evaluated and tested the aircraft sustainability model (ASM), which will be used for WRSK/BLSS requirements and budget execution, and we will define how Dyna-METRIC can be used to compute spare engine levels.

Evaluation of Aircraft Spares Demand Forecasting Techniques: The objectives of this study are twofold:

(1) To gain a thorough understanding of how the characteristics of an item (price, demand pattern, etc.) and the technique chosen to forecast the item's total organization intermediate demand rate (TOIMDR) (24-month moving average, equipment specialists' estimate) and total base not reparable this station (NRTS) percentage combine to effect the "goodness" accuracy, resulting shortages or excesses, etc., of the forecast in both the short (for repair projections) and the long (for buy projections) terms.

(2) To develop practical guidelines for equipment specialists and the recoverable consumption item requirements system (D041) to use in selecting the most appropriate demand forecasting techniques for each item in both the short and long terms.

Engine Pipeline Study: The objective of this study is to review, develop, and improve upon the current pipeline reports and to develop methodologies to compute proposed pipeline standards for peace and for war. Our approach includes (1) establishing a data base covering 18 months for 9 engines, (2) analyzing basic pipeline segments, (3) developing/adapting models to forecast pipeline times for large segments given probabilities and times for basic segments, (4) developing methodology for computing standard pipelines for peace and war, and (5) developing prototypes of improved reporting displays and computational methodologies.

The senior staff consists of:

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government or developed by outside contractors or consultants, should recognize and account for the unique circumstances found in government applications of EDI.

Conclusion

The use of EDI, by both industry and government, is fast becoming a reality. While the present use of EDI is still very small when measured as a percentage of total transactions, its use is pervasive across all facets of business and industry. The foundation has been set for very rapid growth of EDI.

EDI offers significant benefits to any user. Although the value of the various benefits of EDI may be different to industry and government users, both groups can gain significantly through the use of EDI. Users from both industry and government need to plan carefully for EDI implementation, taking into account problems which may be unique to any specific application. However, with careful planning and implementation, the use of EDI will significantly improve logistics performance for all users.

References

1. Abend, Jules. "UPC = OR = JIT Inventory," *Stores,* May 1987, pp. 44-54.
2. Akerman, G. C. *Introduction to EDI: A Primer,* General Electric Company, 1985.
3. "An Electronic Pipeline That's Changing the Way America Does Business," *Business Week,* 3 August 1987, pp. 80-82.
4. Bartley, Jack. "EDI in the Department of Defense," presentation at EDI: "Bringing it Together in Government," Gaithersburg MD, 26 May 1988.
5. Canright, Collin. "EDI: The Acronym That Means Business," *Systems/3x World,* January 1987, pp. 21-23.
6. Carroll, Paul B. "Computers Bringing Changes to Basic Business Documents," *The Wall Street Journal,* 6 March 1987, p. 33.
7. "Detroit Tries to Level a Mountain of Paperwork," *Business Week,* 26 August 1985.
8. "EDI: Data on the Fast Track," *Distribution,* June 1987, pp. 38-41.
9. "EDI is coming at You," *Information Week,* 5 October 1987, pp. 20-27.
10. "EDI Puts the Buyer in Control," *Purchasing World,* March 1987.
11. Emmelhainz, Margaret A. "EDI: The Impact on the Purchasing Process," *Freedom of Choice,* NAPM, 1987, pp. 23-31.
12. Holevar, Gregory D. Chief, Transportation and Policy, Air Force Logistic Command, Department of the Air Force, personal interview, March 1988.
13. Hostetter, Ralph. "EDI for Purchasing," presentation at EDI: "Bringing it Together in Government," Gaithersburg MD, 26 May 1988.
14. LaLonde, Bernard J. "Customer Service: Making it Happen," 1987 Annual Conference of the Council of Logistics Management, Atlanta GA, September 1987.
15. "Military Stores Advance on EDI," *EDI Executive,* October/November 1987. p. 5.
16. Norris, Richard. "Computer to Computer Communications: Uses and Prospects," *Logistics Notes,* Arthur D. Little, Inc., 1986.
17. Palmer, James, Rundle, Steve, and Smoyer, Frank. "MAGIC: Paperless Contracting for the Real World," *Proceedings of the Society of Logistics Engineers,* 22nd Annual Symposium, 1987, pp. 207-214.
18. Parsons, Bobby. "EDI in the Department of Defense," presentation at EDI: "Bringing it Together in Government," Gaithersburg MD, 26 May 1988.
19. Rush, Tom. "Steps to EDI Implementation," *Network World,* Volume 5, No. 9, 29 February 1988, p. 21.
20. Saltman, Roy. "EDI in Government," presentation at EDI: "Bringing it Together in Government," Gaithersburg MD, 26 May 1988.
21. Stromberg, Ken. "EDI in the Department of Defense," presentation at EDI: "Bringing it Together in Government," Gaithersburg MD, 26 May 1988.
22. Strong, Charles. "EDI in the Department of Defense," presentation at EDI: "Bringing it Together in Government," Gaithersburg MD, 26 May 1988.
23. "Toys-R-Us: Its Recent Turnaround Wasn't Child's Play," *Information Week,* 14 December 1987, pp. 24-26.
24. Wallace, William. Systems Analyst, Army and Air Force Exchange System, Dallas TX, telephone interview, April 1988.

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